SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

FULL ABSTRACT BOOK

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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SESSION 1

ASTRONOMY AND GEO-SPACE OBSERVATIONS FROM ANTARCTICA

Tony Travouillon
Lucilla Alfonsi, Adriana Gulisano, Jennifer Cooper

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Ionospheric TEC and scintillation climatology at SANAE station

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We report on an unprecedented climatological assessment of ionospheric scintillations and TEC gradients at Antarctic sub-auroral/auroral latitudes observed from the South African Antarctic station, SANAE IV (71°40’22”S, 2°50’26”W). The station is equipped with a Septentrio PolaRxS receiver providing access to ionospheric delay and related measurements from not only the GPS system of navigation satellites but also from the Russian GLObal NAvigation Satellite Systems (GLONASS) and European Galileo satellites. The field of the GNSS satellites in view from the station is mainly sub-auroral, but under perturbed geospatial conditions it can enter the auroral oval.
Our assessment of TEC and ionospheric scintillations is based on the data acquired along the period 2017-2019 and shows frequent occurrence of moderate to high σΦ level. The S4 climatological behavior testifies an infrequent occurrence of moderate amplitude scintillation. The σΦ index considered in our analysis is provided by the receiver firmware applying a cutoff frequency of 0.1 Hz for detrending. The detrending is necessary to remove the effect on the phase of the signal due to the relative velocity between the transmitter (onboard the satellite) and the receiver (at ground) and the slowly varying background ionosphere. A cutoff frequency of 0.1 Hz means to assume a relative velocity of about 40 m/s that is often inappropriate to describe the dynamics of the high latitude ionosphere. In such a framework we will critically discuss the “phase without amplitude” scintillations observed over SANAE.

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Keeping telescope optics free from ice on the Antarctic plateau

Michael Ashley[1]
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The formation of ice on the optical elements of telescopes has been a long-term problem in Antarctica that has resisted a satisfactory solution. Various techniques have been tried, such as the use of desiccants for internal surfaces, indium tin oxide coatings on external windows, and hot air. Some of these techniques have negative effects on the astronomical observations, e.g, indium tin oxide will absorb some of the incoming light, and heating an element can introduce air turbulence.

This talk will review the physics of ice formation and sublimation under the unique conditions prevailing on the Antarctic plateau. There are been recent relevant experimental results, and atomic force microscopy of water molecules on metal surfaces. Proposals will be made for techniques to measure ice formation, and to efficiently eliminate it, while minimizing the effect on astronomical observations.

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The Greenland Telescope

Mingtang Chen[1]
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The Greenland Telescope (GLT) has been participating in global very-long- baseline-interferometry (VLBI) observations from Thule Air Base since the spring of 2018. Located in northwestern Greenland, the telescope has provided an important northern location for global VLBI campaigns for studying supermassive black holes. The telescope has been completely rebuilt and commissioned, with many new components, from the ALMA North America Prototype antenna and equipped with a new set of sub-millimeter receivers operating at 86, 230, and 345 GHz, as well as a complete set of instruments and VLBI backends. This paper reports our progress of fine-tuning the telescope and the operational status from the past two years (2018 - 2020) for this unique submillimeter telescope in the Arctic Circle.

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Challenges and evolution of the ITM Antarctic telescope design

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The International Telescope Maffei (ITM) is a f/21.16 Cassegrain telescope located at Concordia Base in Dome C, Antarctica. The telescope has been developed as a project hosted by the Italian Programma Nazionale di Ricerche in Antartide (PNRA) and Consiglio Nazionale delle Ricerche (CNR) and has been operating in Concondia since 2005.
Over the years of activity several modifications have been made in order to increase the robustness of the system adopting new technologies and materials.
Moreover, during this period, the telescope facility received many observing proposals who challenged its observing capabilities and required to push the telescope initial limits even further.
Two years ago the ITM facility underwent a major upgrade starting from the refactorization of the whole control system.
The thermalized boxes containing the control devices and instruments have been re-designed to take into account the experience gained in the years.
The new telescope facility is focused on simplifying any human intervention in the system through a redundant, distributed and fully autonomous thermal control.
In this contribution we present the last step of the telescope upgrade, the new box design and new control system together with the lightweight web-app used to monitor and supervise remotely the facility even from Europe through the Concordia Base VPN and the main observing challenges that the telescope foresees in the next years.

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Impact of the South Pole Telescope (SPT) on Galaxy Cluster Science

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In this review-style presentation, I will discuss how the South Pole Telescope (SPT) has laid the groundwork and made significant contributions towards the science of studying galaxy clusters. Numerous space- and ground-based telescopes utilize surveys completed by SPT, and I would like to highlight these accomplishments from the past decade. Additionally, I'll cover the advantages of polar-located observatories, how SPT surveys of clusters compare to other surveys, and how future projects such as the James Webb Telescope can further the discoveries completed by SPT.

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Ionospheric response to the June 2015 geomagnetic storm in the South American region

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The ionospheric dynamics in the South America (SA) sector during geomagnetic disturbed period from 21 to 24 June 2015 is investigated through ground ionosonde stations and Global Navigation Satellite System (GNSS) receivers. These disturbances were caused by 3 interplanetary shocks (IS) derived from 3 consecutives coronal mass ejections (CME) from the same solar active region; the first two CME were caused by filament eruptions, and the third was a much larger full halo CME, associated with a M2.6 solar flare. The first 2 shocks were compressive and did not cause an immediate response to the ionosphere in the analyzed region, while the third shock increased considerably the electron density from low to high-latitudes, triggering the second strongest geomagnetic storm of the 24th solar cycle. It was possible to observe the expansion of the crest of equatorial ionospheric anomaly (EIA) at midlatitudes and high-latitudes mainly due to prompt penetration electric field (PPEF) during the main phase and the recovery phase of the geomagnetic storm during the day.

1307

Two-colour photometry to search for transiting exoplanets with ASTEP at Dome C, Antarctica

Nicolas Crouzet[1], Tristan Guillot[2], Lyu Abe[2], Djamel Mékarnia[2], Karim Agabi[2], Yves Bresson[2], Christophe Bailet[2], Nicolas Mauclert[7], Ana Heras[1], Pierre Ferruit[1], Amaury Triaud[3], Anne-Marie Lagrange[4], François-Xavier Schmider[2], Giovanna Giardino[1], Kate Isaak[1], Ralf Kohley[5], Daniel Michalik[1], Bernard Foing[1], Göran Pilbratt[1], Anamarija Stankov[1], Philippe Gondoin[1], Stephan Birkmann[6], Laurence O'Rourke[5]

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Dome C in Antarctica provides exceptional conditions for photometry thanks to the continuous night during the Antarctic winter, a high clear sky fraction, low wind speeds, and a cold and dry atmosphere. The ASTEP project (Antarctic Search for Transiting ExoPlanets) aims at detecting and characterising transiting exoplanets and qualifying this site for photometry in the visible. The main instrument, a 40 cm telescope, has been designed to perform high precision photometry under the extreme conditions of the Antarctic winter and has operated at the Concordia station since 2010. It will be upgraded with two new cameras and a new camera box in order to provide simultaneous two-colour photometry and substantially increase its throughput. The new setup will be operational for the winter campaign 2021 and will allow us to discover transiting exoplanets orbiting bright stars in particular low mass exoplanets, temperate exoplanets, exoplanets around young stars, and to refine the ephemerides of exoplanets discovered by the TESS mission. These observations will provide targets for first characterisation with the CHEOPS mission and atmospheric studies with the JWST and ARIEL missions. In this talk, I will describe the science goals and the upgrade of the ASTEP telescope.

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Searching for long period transiting exoplanets with ASTEP South at Dome C, Antarctica

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Much of our understanding of gas giant exoplanets come from those transiting in front of bright stars at short orbital separations (P ~ 3 days, a ~ 0.05 au). However, these "hot Jupiters" are coupled to their host stars: the strong irradiation and tidal interactions impact their orbital and physical properties. In contrast, "cold Jupiters" (P > 30 days, a > 0.2 au) are largely decoupled from their host stars and those transiting bright stars provide ideal benchmarks to study gas giant exoplanets. The 4-month continuous night during the Antarctic winter combined with excellent weather conditions is favorable to the detection of long period exoplanets, which are not accessible from temperate sites. We analysed four winters of photometric data collected with the ASTEP South instrument at Dome C and identified transit candidates with long orbital periods around bright stars. We conducted photometric follow-up of these objects using the 40-cm telescopes of the Las Cumbres Observatory Global network of Telescopes and we analysed their lightcurves extracted from the full frame images of the NASA TESS mission. In this talk, we will present these objects and the results of the photometric follow-up.

1340

The IceCube Upgrade Detector Project

Michael DuVernois[1]
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The IceCube Neutrino Observatory is a gigaton Cherenkov detector in full operation at the South Pole since early 2011. An enhancement to the observatory is currently under construction with expected deployment in the Austral Summer of 2022-2023. This in-fill detector will consist of about 700 closely-spaced optical modules plus calibration devices and R&D sensor modules. The project goals include neutrino oscillation physics, improved ice property measurements (and resulting systematic improvements to all IceCube data), and development of hardware for a next generation (Gen2) IceCube expansion for high-energy astrophysical neutrinos.

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NIAOT activity around Antarctic Astronomy

Xuefei Gong[1]
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From small optical telescope-CSTAR, NIAOT have made solid progress in Antarctic astronomical instruments, this talk will give brief introduction about current situation of updated moveable Cstar, third AST3 and KDUST.

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Space weather events and the possible impact on the temperature and ozone profiles at the Antarctic peninsula

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Disturbances in the terrestrial space environment can be caused by Space Weather events such as Geomagnetic storms, solar and interplanetary events that can last hours or days. Some episodes of transport and dissipation of energy in the ionosphere and magnetosphere named magnetospheric substorms are more frequent than geomagnetic storms but have shorter duration spanning from 10 minutes to a few hours. In this work we addressed the variability of temperature and ozone profiles at the lower and middle stratosphere at the Antarctic Peninsula during the mentioned space weather events.
We analyzed ozone-radio soundings at the Argentinean Marambio Station provided by the National Meteorological Service of Argentina and the Meteorological Institute of Finland from at solar cycles 23 (1998-2008) and 24 (2009-2018) taking into account strong and moderate geomagnetic storms and larger substorms.
We consider the Dst and AE indices that provide respectively a measure of the intensity of the energy contained in the Ring Current and a quantitative measure of the auroral magnetic activity, useful for the analysis of individual substorms.
We studied also the changes in the partial pressure of ozone (ppO3) during these events, for levels 9-13, 14-19 and 20-26 km, where the greatest variability of ozone occurs (Morozova et al. [2016]).
We present our preliminary results that will be useful to better understand the possible impact of Space Weather events on the Antarctic atmosphere.

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A Cosmic Rays Observatory in the Argentine Marambio station at Antarctica: the first permanent Antarctic Node of the LAGO collaboration

Adriana Maria Gulisano[1,2,3,6], Sergio Dasso[2,4,6], Omar Areso[2,6], Matias Pereira[2,6], Noelia Santos[4,6], Viviana Lopez[5], Maximiliano Ramelli[2,6], Lucas Rubinstein[2,6], For the LAGO Collaboration LATIN AMERICAN GIANT OBSERVATORY see list of members at http://lagoproject.net/collab.html[6]
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The Antarctic continent has the combined advantage for the installation of astroparticle detectors: (a) enough infrastructure in Antarctic stations, and (b) low geomagnetic field rigidity cut off, which allows the arrival of a huge flux of low energy particles, permitting a large amount of information related with physical processes in space.

LAGO (Latin American Giant Observatory) is a collaboration, forming a net of cosmic rays detectors based on water Cherenkov radiation. LAGO has nodes spanning from Mexico to Antarctica. Antarctic LAGO nodes allow to study particle fluxes that in middle latitudes won't be able to reach ground level since they are shielded by the geomagnetic field.

In this work, we will present results of the deployment and installation of a Space Weather laboratory, developed by the LAMP group (Laboratorio Argentino de Meteorología del esPacio, the Argentinean Space Weather Laboratory) during January-March 2019 at the Argentine Marambio station.
This Antarctic laboratory has a LAGO node (i.e. a Water Cherenkov
detector) in operations from March 2019. We also present the improved facilities of the laboratory and improvements of the operations of the detector developed during January-March 2020

The calibration and first results of the cosmic rays detector will also
be presented, as well the operative use of the real time data, which are transmitted to the servers of LAMP in Buenos Aires, and are publicly offered, and used to operative Space Weather activities by LAMP

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Operative Space Weather products offered by LAMP (Argentinean Space Weather Laboratory group)

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The Argentinean Space Weather Laboratory (LAMP) became a new regional warning center of ISES (International Space Environment Service) in January 2020. LAMP carries out several operative space weather (SW) activities since 2016. For instance, they produce daily monitoring of real-time information (space and ground-based instruments) on SW, a weekly bulletin which synthesizes the most relevant information, an alert system for extreme SW conditions, and participates in monthly briefings to discuss the situation of the previous days and generate ideas for new products. New operative SW products were developed by LAMP to better identify perturbed conditions in the Sun-Earth system. A study with energetic electron fluxes measured by GOES was carried out to develop a product that shows three different thresholds associated with low, medium and high perturbed conditions. Also, LAMP worked out a solar wind product with plasma and magnetic field data from ACE spacecraft. Moreover, real-time data from the water Cherenkov particle detector at Antarctic (Neurus) is included as a new product. This detector was installed by LAMP at the Argentine Marambio base during January-March 2019. In this work, we present details of some of the new operative Space Weather products developed in the LAMP group.

1614

Understanding the Expansion of Universe with South Pole Telescope

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The South Pole Telescope (SPT) is a 10-meter telescope located at the Amundsen-Scott South Pole station in Antarctica. The telescope is operating for over a decade and has completed 2,500 $\deg^2$ of SPT-SZ survey, 500 $\deg^2$ of SPT-pol survey and is currently in its 3rd generation (SPT-3G) to observe 1,500 $\deg^2$ of the sky with unprecedently low noise levels of 3 μK-arcmin. In this talk, I will present some of the major scientific results published in last couple of years. I will focus on the sub-millimeter wavelength properties of galaxy clusters and the anisotropies in cosmic microwave background (CMB) radiation. I will present the newly discovered galaxy clusters with this instrument along with a deep learning approach to estimate their mass. I will show recent cosmological results using galaxy clusters. I will present the CMB temperature power at high multipoles and recent advances in B-mode science with this instrument. And finally, I will show the statistical and the polarization properties of Active Galactic Nuclei (AGN) in clusters and in field.

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Five-year meteorological data from KLAWS for astronomical site testing at Dome A, Antarctica

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We present and compare meteorological data of nearly five years from KLAWS (Hu et al. 2014) and KLAWS-2G (Hu et al. 2019). Both facilities are automated weather stations with multiple temperature sensors and anemometers at several elevations from 2 m to 14 m. By analyzing the data, we find that a strong temperature inversion (TI, temperature gradient could reach up to 7°C/m at 4 m) exists just above the ground surface for 50% or more of the time at all the elevations. The average wind speed at 4 m is around 4.0 m/s, the wind speed is seldom larger than 10.0 m/s. The strong TI and moderate wind lead to a stable atmosphere and a shallow boundary layer, above which we could obtain superb free-atmosphere (FA) seeing. Comparing monthly median values of temperature, TI and wind speed in different years, we find the climate at Dome A exhibits obvious annual variation. Finally, by correlating simultaneous data of 1.5 months from KLAWS-2G and KL-DIMM in 2019, we find that the FA seeing prefers to existence of strong TI. Therefore, the data from KLAWS are important for understanding atmospheric turbulence and can possibly be used to estimate the seeing at Dome A.

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Simultaneous observation of ionospheric plasma drift and thermospheric winds at Jang Bogo station, Antarctica

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In the high-latitude ionosphere, the plasma motion is mainly driven by the magnetospheric forcing and it is intimately coupled to the neutral motion via ion-neutral collisions. In other words, the neutral winds in the high-latitude region are controlled by the magnetospheric forcing, rather than solar EUV forcing. However, in spite of this well-known close coupling between ion and neutral motions in the polar region, specific details of the coupling processes are not well understood mainly due to the lack of observations of the ion drift and neutral winds. Since the establishment of Jang Bogo Station in Antarctica, Korea Polar Research Institute (KOPRI) has been operating Vertical Incidence Pulsed Ionospheric Radar (VIPIR) and Fabry-Perot interferometer (FPI) to simultaneously observe the ionosphere and thermosphere near the boundary between the auroral and polar cap regions. In this study, we used 3-year (2017-2019) measurements of the ion drifts and thermospheric winds from these instruments in order to investigate how closely they are coupled to each other under various geophysical conditions. The initial results of the study indicate that the background ionospheric density is one of the key parameters controlling the coupling processes. We will further use the TIEGCM simulation to verify the results of the analysis of the data.

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Polar thermospheric wind measurements at polar cap and aurora oval regions

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We present thermospheric winds from the ground-based Fabry-Perot Interferometer (FPI) at 630.0 nm airglow emission over two Arctic regions. Neutral dynamics at polar thermosphere are driven not only by a solar-induced pressure gradient force but also by ion drag effects from magnetosphere-ionosphere coupling. Korea Polar Research Institute has been operating two FPIs in Longyearbyen, Svalbard and Esrange, Sweden to uniquely study how polar thermospheric winds respond to different geomagnetic conditions with respect to different latitudes. In this study, we briefly introduce our preliminary results of neutral wind derived from FPI 630.0 nm emissions over two arctic regions.

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Measuring the turbulence profile at Dome A with AST3

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Dome A is characterized by a very thin boundary layer, the thickness of which is critical to determine the minimum height of future telescopes. We have developed a novel method, the Multistar Turbulence Monitor (MTM), to measure the low-altitude turbulence profile, Cn2, using the Antarctic Survey Telescope (AST3). As is well known, the stellar image motion seen in very short exposures reflects turbulence intensity. AST3 can capture dozens of bright stars, even with 10-ms exposures, due to its 4.3-deg2 field-of-view and 0.5-m diameter. The differential motions between star pairs, which are not affected by telescope vibration, are sensitive to certain height ranges of turbulence as a function of the separations between stars. By combining the differential motions between star pairs over a range of separations, we can estimate the low-altitude Cn2 profile, the high-altitude seeing and the outer scale. Here we will report the preliminary results from observations by AST3 in 2017. In optimized fields, there were typically ~50 stars having separations ranging from 0.05 to 2.3 deg, giving a sensitivity to turbulence within ~500 m above the telescope. We will introduce the data reduction technique, Cn2 profile reconstruction method and the main results.

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A Decade of Discovery: Results from the IceCube Neutrino Observatory

James Madsen[1]

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The IceCube Neutrino Observatory at the South Pole, now in its tenth year of full operation, has a remarkably wide and expanding science reach. In addition to discovering the first high-energy astrophysical neutrinos and measuring their spectrum, IceCube has delivered on one of its primary goals, establishing the field of neutrino astronomy with real-time alerts. An overview of highlights from the last decade, including identifying the first point source of high-energy neutrinos (blazar TXS 0506+056), competitive neutrino oscillation measurements, and world-leading constraints on sterile neutrinos, dark matter, Lorentz invariance, magnetic monopoles, and physics beyond the Standard Model will be provided. The plans for next generation of the observatory, IceCube-Gen2, will be presented.

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Development of an Optical Robotic Observatory at the Argentine Antartic Base Belgrano II

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We have designed and constructed an infrastructure made of poliestyrene fiber to house a telescope with a tube of up to 1.6m of length, as for example a 50cm f/3 Cassegrain. The infrastructure consists of a 2.5m diameter rotating dome, with an upper door shutter of kite-type opening, mounted on a cylindrical building 1.6m high. The building sits on a 1.5m high galvanized iron platform. Naturally the telescope pillar and infrastructure are decoupled mechanically.

All the designs are original, including for example the coupling between the dome and the building, its anti-tilt system, the motorization of the shutter, etc. Efforts due to wind gusts of up to 300 km/h at a temperature of around -20oC were simulated numerically, checking that the design is resistant to those conditions. We estimated an anchoring force of approximatelly 1.5Tn. All the materials used are stable at low temperatures of up to at least -40oC. This infrastructure is planned to be installed in the area of Belgrano II Base (Latitude 77:32:28 S, Longitude 34:37:37W) by the southern's hemisphere summer of 2020-2021. The galvanized iron platform has already been installed by the base in the past southern hemisphere's summer.

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Historical supernova signatures in an Antarctic ice core

Yuko Motizuki[1]
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Gamma rays associated with nearby supernova explosions can cause changes in the chemical composition of the stratosphere from ~8 – 50 km altitude of the earth. The effect can then be recorded in the chemical composition of polar ice. Ice cores drilled at Dome Fuji station in Antarctica preserve mainly chemical components of the stratosphere, and hence worth studying traces of historical supernovae.

In this talk, I will focus on yearly-scale spikes that were observed in nitrate ion concentration profiles in a Dome Fuji ice core. We diagnose the yearly-scale spikes with respect to precision, reproducibility, and dating uncertainty, and discuss whether or not the spikes can be the traces of historical supernova explosions in our galaxy. Special attention will be given to SN1006 and SN1054. The energetics of the production of nitrogen oxides in the stratosphere induced by nuclear gamma rays from a galactic supernova will also be discussed. Since nitrate spikes are almost coincident with the dates of the known galactic supernovae within dating uncertainty, we propose that the yearly-scale nitrate spikes embedded in the Dome Fuji ice core be regarded as candidate signatures of supernovae that have occurred in our galaxy.

1678

Advances on the Development of a Peruvian Space Wheather Station

Luis Otiniano[1], Cynthia Bello[2], Juan Vega[1], Jorge Samanes[1]
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As part of iour space weather program we are developing instrumentation aimed at studying the near-Earth space environment from the ground. Space weather studies in Antarcti are favoured because the direct coupling of the ionosphere the Earth's magnetosphere. We are testing the instruments during the last three Peruvian summer campaigns in Antarctica (ANTAR XXV, XXVI and XXVII). One of the instruments is a water Cherenkov detector of the Latin American Giant Observatory (LAGO, www.lagoproject.net) the other one is a vertical very low frequency (VLF) receiver.Here we present results of the validation of both instruments and the perspectives for their permanent operation in the Antarctic.

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Features of GNSS signal outages from nearly conjugate polar locations

Ashik Paul[1], Dibyendu Sur[1]
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GNSS signals are increasingly being used for characterizing detrimental impact of ionospheric irregularities on satellite-based communication and navigation systems and services, and the resulting signal outages. The polar regions of the Earth are some of the most challenged in terms of maintaining high levels of performance of GNSS from the operational point of view with mitigation strategies for cycle slips and loss-of-lock of the satellite signal by the receiver.
In the high latitudes, highly dynamic ionospheric irregularity structures encompassing scale sizes from hundreds of kilometers down to a few centimeters co-exist with varying convective motion determined by interplanetary magnetic field (IMF). The dynamics of these irregularity structures have a seasonal dependence being more convective in the winter hemisphere. In the present paper, data have been analyzed from the two stations, namely, Eureka Bay (87.65°N,91.57°W geomagnetic) and Concordia (83.90°S,138.72°W geomagnetic), located in the Arctic and Antarctic regions corresponding to four geomagnetic storms which occurred over the period 2012-13, within the framework of a GNSS project at the International Space Science Institute (ISSI).
It is found that the observed cycle slips are more or less correlated with intensity of Auroral Electrojet. The number of cycle slips observed at Concordia near the South pole are more than that observed from Eureka Bay located close to the North pole. The differences have increased in March 2012 and March 2013. This difference may possibly be attributed to more particle injection at South pole than the North pole.

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The SWIT-eSWua system: a cutting-edge infrastructure to access ionospheric data in polar areas.

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The polar regions are a privileged natural laboratory for the investigation of the ionosphere. Regular observations can provide timely information for the monitoring, forecasting and mitigation of the effects on modern technologies (such as telecommunication systems, power networks and in general systems relying on satellite navigation) during Space Weather events.

The Upper Atmosphere Physics and Radiopropagation group at the Istituto Nazionale di Geofisica e Vulcanologia (INGV, Italy) has a long tradition in managing ionospheric data and currently operates, among others, GNSS receivers for scintillation and TEC monitoring in Antarctica (Mario Zucchelli, Concordia and SANAE IV stations) and in Svalbard (Ny-Ålesund and Longyearbyen). The activities at polar latitudes are also included in the SCAR expert group GRAPE (GNSS Research and Application for Polar Environment, www.grape.scar.org).

Inspired by Open Science principles, the SWIT (Space Weather Information Technology) infrastructure coupled with the eSWua (electronic Space Weather upper atmosphere) web-platform provide Findable, Accessible, Interoperable, Re-usable (FAIR) ionospheric data from the INGV network in near real-time. In addition, the SWIT-eSWua system ensures the access to operational monitoring products related to the nowcasting and forecasting of different ionospheric parameters. This, with the aim to serve the scientific community as well as the Institutional stakeholders (like civil protection, civil aviation, etc.).

In this work the state of the art of the SWIT-eSWua system is described focusing on Arctic and Antarctica, together with examples of the products developed in the framework of national and international initiatives.

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Ionospheric response to annular and partial solar eclipse of 29 April 2014 in Antarctica and Australian Regions

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Solar eclipse is one of the important solar terrestrial events which have a direct impact on Earth's ionosphere. A solar eclipse provides us with a rare opportunity to study the ionospheric effects associated with an accurately estimated variation of solar radiation during the eclipse period. An annular and partial solar eclipse was observed on 29 April 2014 over Australian and Antarctic regions. In this study we have analyzed the ionospheric response of this solar eclipse event. We have done a comprehensive study to find out the changes that occurred in various ionospheric parameters during the solar eclipse event over Australia and Antarctic region. We selected four Australian stations Brisbane (27.5∘S, 152.9∘E), Canberra (35.3∘S, 149.1∘E), Hobart (42.9∘S, 147.3∘E) and Perth (31.955∘S, 115.859∘E) as well as one Antarctic station Mawson (70.6455∘S, 131.2573∘E). We have studied the changes in the E and F ionospheric layers using the ground based observations at these stations. From our analysis we found that there occurred a decrease in the critical frequencies of sporadic E ($foEs$) and F ($foF2$) layers during the time eclipse was in progress at all the four Australian stations while as at Antarctic the value of $foF2$ recorded an enhancement. At the same time an increase in the corresponding heights of these layers ($h'Es$, $h'F2$) was also observed.
KEYWORDS: Annular solar eclipse; ionospheric parameters; sporadic E; critical frequency.

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Astronomical Seeing at Dome A in 2019

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Following the installation of several unattended site testing instruments at Kunlun Station, Dome A in early 2019, we were able to operate KL-DIMM successfully to directly measure astronomical seeing through the winter for the first time. KL-DIMM is installed on a tower at a height of just 8 meters. Very good free-atmosphere seeing was detected above a thin boundary layer, comparable to that at a 20 m height at Dome C. We also find that the seeing and boundary layer thickness are correlated with local temperature inversion which is monitored by KLAWS, a multi-layer automatic weather station. These results further support Dome A to be a good site for optical/infrared astronomy.

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A Path for Infrared Astronomy at Dome C

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The Antartic conditions are ideal for astronomical observations in the infrared. The Domes in particular offer combination of cloud cover, seeing and sky brightness that still remain under-exploited. We propose a path forward for the development of infrared observations at Dome C. A first phase consisting of equipping the existing telescopes with infrared cameras will allow for deep observations of the infrared sky and establishing the infrastructure and experience to make such observations routine on the ice. As a second phase, we propose to establish a state of the art IR survey telescope with aperture of 1m that will focus on the seach of gravitational wave event follow-up.

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The unique polar perspective for Space Situational Awareness

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Artificial satellites encircle the Earth in elliptical trajectories that give rise to unique virtual ground tracks across the surface of the planet depending upon the characteristics of their orbit. Given the distribution of orbital inclination angles for objects in the public catalogues, the number of satellites that are visible each day strongly depend upon the observers location. The polar regions offer a factor of 2 improvement in observable satellite numbers over mid-latitude locations. This makes Antarctica a prime location for the observation of artificial satellites.

An important part of Space Situational Awareness is the determination or refinement of orbital parameters to improve our understanding of where objects are in space. In order to maintain a comprehensive and actionable catalogue, a very large number of objects must be routinely observed as they transit across the sky. Due to the improved object visibility at the poles, Antarctica offers a unique vantage point from which to maintain a global catalogue of man-made objects in space.

In this talk we detail the potential and parameters influencing the performance of SSA observatories in Antarctica. We describe the implications of finite data bandwidths and how these may be overcome by new communications opportunities such as satellite optical links. We also introduce SSA technologies in development with Curtin University and Lockheed Martin Australia which currently address communications and automated operation issues and are well suited to Antarctic deployment.

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Immersive Rendering and Sonification of Large Scale Antarctic Astronomy Data in Virtual Reality: The Making of INSTRUMENT | One Antarctic Night

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INSTRUMENT | One Antarctic Night is (IOAN) is a multi-player virtual reality (VR) art + science installation created from data captured by the Antarctic Survey Telescope (AST3) on Dome A of 817,313 astronomical objects at the center of the Large Magellanic Cloud.

Watch 3 minute video: https://vimeo.com/352807613. Website: http://oneantarcticnight.com/

Immersed in a VR arena, three participants sonify data from the 817,313 individually manipulable astronomical objects as a musical instrument to create a never ending sound scape. Real-time database queries, selections, and filtering operations in VR enable immersed participants to collaboratively interact with the objects to remix and sonify the astronomical data. All of the graphics and sound are procedurally rendered in real time from the data. GAIA DR2 and SIMBAD data are cross referenced with AST3 data, in addition to analysis of AST3 time-series data with algorithms from Vartools, Astropy and some machine learning. For IOAN we created the VR Arena as a new kind of social multiplayer immersive experience. Spatially distributed 4K physical portals combine with multichannel spatialized ambisonic audio and multiple VR interactive systems each with individual user spatialized audio. Immersed participants perform astronomical data as a sonic composition for spectators to the VR Arena that see and hear the virtual world in correct spatial relation to their real world position in the exhibition space. Player point-of-view is shown on additional dedicated displays inside the arena. IOAN explores the beauty and the rhythms of the cosmos observed from Dome A during AST3's first Antarctic night of service.

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Sporadic E layers during the Weddell Sea Anomaly under the different levels of solar activity as deduced from observations at the Akademik Vernadsky station

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Sporadic E layers (Es) are the plasma structures characterized by increased electron concentration or intensive plasma irregularities located at the heights of E region. The occurrence, disappearance and variability of Es are irregular. But Es heights demonstrate good repeatability from day to day and possibly show the location of wind shear in the lower thermosphere. Since Es depend on winds, it looks interesting to analyze their behavior in the region of Weddell Sea anomaly (WSA) that is appeared as a result of strong impact of thermospheric winds on the main ionospheric plasma characteristics. We are analyzing the Es data accumulated during 22 years at the Ukrainian Antarctic station Akademik Vernadsky located in the heart of WSA. It was found that the heights of Es at the nighttime are bigger under the high solar activity and lower at the low one. At the daytime the situation is opposite, Es heights are bigger under the quiet Sun conditions. The explanation of those dynamics could be the next. The horizontal gradients of the temperature, pressure and as a result the wind speed in lower thermosphere should increase with growth of solar UV flux and decrease in opposite case. That should lead to decreasing the height of wind shear at the daytime when polar-ward thermospheric winds are prevailed, and to upwelling the wind shear near midnight with equator-ward thermospheric winds. The morphology and causes of this phenomenon will be discussed in detail.

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HF diagnostics of natural and artificially stimulated ionospheric irregularities at the Akademik Vernadsky station (Review)

Andriy Zalizovski[1,2,3], Yuri Yampolski[1], Gennady Milikh[4], Evgeny Mishin[5], Alexander Koloskov[1,3], Sergei Kashcheyev[1], Bogdan Gavrylyuk[1,3], Artem Reznychenko[1,6]

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We report on the results of global diagnostics of ionospheric irregularities using coherent monitoring of HF signals. Radio signals were radiated by high-power HF heating facilities such as HAARP (Gakona, Alaska, USA), EISCAT (Tromsø, Norway), and Arecibo (Puerto Rico, USA) as well as by transmitters of time service in Europe (RWM, Russia) and Northern America (CHU, Canada) propagated on super long radio lines and detected at the Ukrainian Antarctic station Akademik Vernadsky (UAS). Simultaneous transmissions of time and frequency service are used as probe signals due to continuous highly stable operation. They have been recorded round-the-clock at the UAS since 2010. Analyses of the RWM signals allowed us to reveal four different pathways: the direct and reverse paths along the great circles and two trajectories formed by focusing along the solar terminator and scattering on the ionospheric irregularities of auroral ovals. The registration of the fourth spatial mode allows us to track the position of the oval and detect the drift velocity of plasma inhomogeneities. The second part of this paper is devoted to study of long-distance propagation of HF signals emitted by powerful heating facilities. Artificially excited irregularities scatter transmitted signals into the ionospheric waveguide formed between the E and F ionospheric layers. Trapping and channeling of waves provide super long-range propagation from the northern to the southern hemisphere. As a result, transmitted signals are consistently recorded at the UAS.

SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 2

POLAR ATMOSPHERIC PROCESSES: WATER CYCLE, SNOW, CLOUDS, AEROSOLS, RADIATION AND GRAVITY WAVES

Takashi Yamanouchi, Damian Murphy
Peter Wilson, Julia Yvonne Schmale, Franzisca Scholder-Aemisegger

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Southern Ocean and Antarctic cloud, precipitation and aerosol observations made from ship- and land-based platforms

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The large warm bias in sea surface temperatures over the summertime Southern Ocean present in numerous climate models is likely due to an incorrect representation of cloud, precipitation and aerosol processes within these models. Specifically, a higher super-cooled liquid water cloud fraction and low levels of anthropogenic aerosols make this region unique on earth. Recent major field campaigns involving aircraft, ships and island have provided key data to allow the community to quantify microphysical properties and characterise the thermodynamic environment in which Southern Ocean clouds exist. We present some highlights of observations made during these campaigns , including ship-based observations of multi-layered super-cooled liquid clouds, supercooled drizzle, ice seeding, vertical profiles of remote marine coarse-mode aerosols and precipitation events over sea ice.

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Activity Concentrations and Sources of 210Pb and 7Be in the Antarctic Peninsula

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The current knowledge of the natural radioactivity in the Antarctica is very limited. The radioactive isotope lead-210 is formed in the atmosphere from radon-222 noble gas, which is nearly solely produced over the land surfaces. For this reason, 210-Pb concentration in aerosol provides a good tracer for a recent continental contact of the air mass. Atmospheric beryllium-7 isotope is formed via the cosmic radiation interactions and deposited with the aerosols and provides also a method to monitor large-scale air mass dynamics.
The activity concentrations of 210Pb and 7Be were determined from the aerosol samples collected in the Antarctic Peninsula, Argentine station Marambio during years 2005-2013 (210Pb) and 2007-2009 (7Be). High-volume (120m3 h-1) aerosol particle samples were collected onto glass-fiber filters (Munktell MGA) and a new filter was exchanged every 2–5 days. The 7Be concentration was determined using semiconductor gamma spectrometry and the lead-210 concentration using the alpha counting of the in-grown daughter nuclide polonium-210 with an automatic alpha/beta analyzer.
The intra- and interannual changes of those radioactive isotope concentrations were determined. Their dependence on the local wind direction was analysed and the source regions determined with a back-trajectory analysis.
In general, very low radioactive concentrations were measured but an occasional continental influence in the air mass was observed.

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Horizontal and vertical propagation of small scale gravity waves observed in 2017 at Ferraz Antarctic Station

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Gravity waves observed at Comandante Antarctic Ferraz Station have been analyzed by using blocking diagrams to estimate the vertical blocking region for the small scale gravity waves observed in 2017. The wave blocking diagrams are constructed by using vertical neutral winds profiles from the troposphere to the mesosphere. The physical parameters of the observed waves were obtained by applying a two-dimensional Fast Fourier Transform (2D-FFT) in a given set of images where a wave event is clearly identified. The investigation of the horizontal and vertical (upward) wave's propagation was conducted by using results from images analyses, vertical wavenumber and blocking diagrams, which are a superposition of the horizontal wind components from the lower troposphere up to the mesosphere. The wind utilized for each night for the blocking diagrams is an averaged wind obtained with all the nocturnal wind profiles. The final average is obtained with the nights where there were observed waves, centered on the new moon, and such averages correspond to the observed month. The winds database was obtained from MERRA reanalysis and from the King Sejong Station (KSS) meteor radar. In this work, it will be presented the wave characteristics, the blocking diagrams, and the vertical propagation conditions near the mesopause. The blocking diagrams well represent the wave filtering, showing the preferential propagation direction of the waves in the mesosphere, i.e., the waves that reach the mesosphere propagates in a different horizontal direction from the average wind in all altitudes levels or are faster than the mean wind.

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Shape, Size, and Qualitative Elemental Compositions of Nano- and Micro-particles Found Within the Ancient Ice of Taylor Glacier, Antarctica, Measured Using Transmission Electron Microscopy and Energy Dispersive Spectroscopy

Cole Bradley[1], Paolo Gabrielli[1], John Olesik[1], Hendrik Colijn[1], Aja Ellis[1]
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Aeolian dust affects Earth's climate directly through the reflection, scattering and absorption of incoming solar radiation and indirectly by acting as condensation nuclei in cloud formation. Iron-containing nanoparticles may also be an important source of iron into the oceans for micronutrient limited phytoplankton which could lead to CO2 drawdown and cycling. In aeolian dust, particles larger than 450 nm account for most of the total mass while nanoparticles smaller than 200 nm are likely greater in number. Nearly all studies of particles entrapped in Antarctic ice have used dissolved, bulk elemental analyses that include particles smaller than 200 nm. Alternatively, Coulter counter particle analyzers are also used to determine particle size distributions for particles larger than 500 nm. We have analyzed individual particles in ice cores from Antarctica's Taylor Glacier, which spans 46.7 ky to 8.7 ky BP, covering Earth's most recent glacial, glacial-interglacial transition, and interglacial period into the Holocene. Transmission Electron Microscopy (TEM) and TEM-Energy Dispersive Spectroscopy (EDS) were used to determine the shape, size, and qualitative elemental composition of many individual nanoparticles. Together, this preliminary characterization could provide insight into changes in Antarctic dust composition, transportation, deposition, and provenance over a glacial-interglacial time scale.

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Polar WRF simulations of Antarctic cloud microphysics at McMurdo Station

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The physics of Antarctic clouds remains poorly understood, and the DOE-NSF AWARE year-long measurement campaign at McMurdo Station, Antarctica was designed to redress this problem. Supercooled liquid water is frequently present at McMurdo, even at temperatures well below -15°C. Yet, numerical models tend to aggressively produce ice condensate at these temperatures. The pristine atmosphere must play some role in the characteristics of Antarctic clouds. Sensitivity experiments with the Morrison two-moment microphysics and other microphysics schemes examine the role of aerosols in simulated Antarctic cloud formation. Furthermore, the complex topography near Ross Island modulates the mesoscale circulations that induce observed cloud structures. Nudging of simulations to the observed radiosondes at McMurdo and regional automatic weather station observations appears to be important to obtain the lower tropospheric conditions observed at McMurdo so that the performance of microphysics parameterizations can be evaluated rather than the simulations being dominated by circulation errors.

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A low cost holographic microscope for cloud and precipitation microphysics studies

Thomas Chambers[1], Murray Hamilton[1], Iain Reid[1]
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Clouds and precipitation play a crucial role in the thermodynamic and hydrological systems of the planet. A key challenge in modelling such processes lies in the parameterisation of particle sizes, shapes and spatial distributions at microscopic scales. This talk will present a low cost instrument for measuring such properties that exploits the technique of digital holography to obtain 3D particle images and allows for automated retrieval of relevant morphological parameters.

Preliminary results from a 2018 field campaign in the Australian Snowy Mountains will be presented along with measurements from Davis Station, Antarctica during 2018-2019. The instrument was deployed in both cases alongside a range of other meteorological instruments allowing calibration and validation of such techniques and potentially providing a means to help in distinguishing pristine particles from wind blown snow based on morphological features.

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Metal atoms and ion layers observed with a frequency-tunable resonance scattering lidar at Syowa

Mitsumu Ejiri K.[1,2], Takanori Nishiyama[1,2], Takuo Tsuda T.[3], Takuji Nakamura[1,2], Makoto Abo[4], Katsuhiko Tsuno[5], Takuya Kawahara D.[6], Takayo Ogawa[5], Satoshi Wada[5]

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The National Institute of Polar Research (NIPR) is leading a prioritized project of the Antarctic research observations. One of sub-project is entitled the whole atmosphere system revealed by precise profiling over the Antarctic. Profiling dynamical parameters such as temperature and wind, as well as minor constituents is the key component of observations in this project, together with a long term observations using existent various instruments at Syowa, Antarctic (69°S, 40°E). As a part of the sub-project, a resonance scattering lidar system with frequency-tunable alexandrite laser was developed and installed at Syowa Station by the 58th Japan Antarctic Research Expedition (JARE 58). Density profiles of minor constituents such as potassium (K), iron (Fe), and calcium ion (Ca+) in the mesosphere and lower-thermosphere (MLT) region were successfully observed in 2017 and 2018. The K and Fe layers were observed 37 and 55 nights in total, respectively, from February to October except April. The Ca+ layer was observed 8 nights in September and October. The MLT temperature was measured by K or Fe lidar measurements. In this presentation, we will show seasonal variations of K and Fe layers and characteristics of Ca+ layer at the high latitude as preliminary results of the frequency-tunable resonance scattering lidar observations at Syowa.

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CRIOSFERA 1 Remote Lab: An automatic and multidisciplinary platform for near-real time atmospheric monitoring at West Antarctica

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CRIOSFERA 1 is the first Brazilian remote atmospheric research laboratory located at West Antarctica (84o00'S, 079o29'39’’W - 667 km from the South Pole). It is endowed with wind and solar systems that allow it to run continuously during summer and winter and transmit data by satellite. Main ongoing research lines comprises: (1) meteorology and snow accumulation monitoring; (2) aerosol composition and black carbon science; (3) physics of high energy; and (4) aerobiology and polar microbiology. At that site we conducted fresh snow d18O(d2H) and air temperature calibration curves for climate reconstruction and have implemented several aerosol sampling methods. Aerosols sampled are submitted to EPMA and multi-element synchrotron-based scanning transmission X-ray microscopy (STXM/NEXAFS). These techniques allowed investigating in details the formation process of the aerosols, their size distribution and how they are formed in terms of composition and molecular structure. Bio-aerosols such as polen grains, spores, palynomorphs, algal fragments and bacteria were detected in Criosfera 1. The laboratory also hosted experiments on snow and ice microbiology trying to help understand how microorganism are transported to West Antarctica and how they persist in the oligotrophic and freezing snow’s environment. Criosfera 1 monitors cosmic rays (muons flux) - CRE@AT (Cosmic Ray Experiment in Antarctica) Project - using plastic scintillators coupled to multianodic photomultipliers. For summer 2020 campaign we intend to start the continuous monitoring of O3, UV-(a/b/c) and bioaerosols. Criosfera 1 is a platform open to international cooperation and exchange of polar experience. Join us (https://www.criosfera1.com)!

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A multi-instrument observational study of the impact of sky condition on atmospheric boundary layer structure and surface radiation over Dome C, Antarctica

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A multi-instrument observational study of the impact of sky condition on atmospheric boundary layer structure and surface radiation over Dome C, Antarctica

Antarctica's pristine environment makes the continent an ideal testbed for studying cryosphere-atmosphere interactions and their variability, and may greatly benefit from combining long-term remote sensing and in-situ measurements. Here, we carry out a multi-year investigative study of the impact of sky condition (clouds, blowing snow) on the atmospheric boundary layer structure and downwelling longwave surface radiation, using ground-based and space-borne observations at Dome C during a 2-yr time period (from May 2009 to April 2011). High vertical resolution profiles of temperature, moisture, and winds obtained from daily upper-air soundings at Dome C, are used to investigate the variability of the atmospheric boundary layer structure. Information regarding sky condition (blowing snow, cloudy, clear) is obtained from quasi-synchronous and contiguous Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) tracks using the Lidar Level 2 Blowing Snow product and Combined CloudSat and CALIPSO (2B-GEOPROF-LIDAR) cloud fraction. High temporal resolution measurements of in-situ surface meteorological variables (temperature, pressure, relative humidity, and winds) and downward longwave radiation are used to estimate the individual and net impact of meteorology, clouds, and blowing snow on the atmospheric boundary layer structure and surface radiation budget. Results based on this multi-instrument study are summarized, highlighting the need for continuous earth observations to monitor and improve our understanding and predictive capability of cryosphere-atmosphere coupled processes.

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Atmospheric Dust and Aeolian Iron: New Lessons Learned from the US Palmer Station, Antarctica

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During the period from November 2015 to January 2017, atmospheric field measurements were carried out at the US Palmer Station located on the Antarctica Peninsula. The primary goal of this research was to quantify the properties of atmospheric dust and aeolian iron under climate warming conditions in the Antarctic Peninsula. To undertake air sampling, a new platform was erected on a rocky hill between the research station and glaciers, and a series of atmospheric instruments were installed on this platform to collect atmospheric aerosols and deposition samples. In this presentation, we will share and discuss our new results, including (1) particle-size distributions of dust and aerosol iron from size-segregated aerosol samples, (2) seasonal variability of atmospheric dust and Fe along with selected organic and inorganic substances based on bulk aerosol samples, (3) atmospheric deposition fluxes of nutrients derived from field measurements and implications for the Southern Ocean biogeochemical cycles, and (4) the potential impact of local and regional dust sources in Antarctica on the composition of the marine atmosphere over the Antarctic Peninsula.

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New insights on the formation and long-term accumulation of perchlorate in West Antarctica

Sérgio Gonçalves[1,2], Heitor Evangelista[1], Ricardo Godoi[2], Johannes Weis[3,4], Tristan Harder[3,4], Swarup China[5], Simon Müller[3,4], Alexander Laskin[6], Mary Gilles[5], Newton Magalhães[1], Bruno Ximenes[1], Heber Passos[7], Magdalena Marques[8], Jefferson Simões[8], Carlos Schaefer[9], Carolina Souza[9]

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The Antarctic environment has been used as a field laboratory for the search of life on Mars. Its dryness, lakes salinities, and the extreme environmental conditions are home to extremely tolerant organisms. The discovery of perchlorate on Mars by the Phoenix Mars Lander addressed the issue of existing liquid water as salty concentrated brines. Perchlorate salts have supercooling properties and high stability. For Antarctica, reports of high perchlorate concentrations were restricted to the DryValleys. Here we present a new insight of higher perchlorate concentrations in West Antarctica/Ellsworth Mountains (1.02 ± 0. 25 mg kg-1 and 25.92 ± 5.58 mg kg-1), suggesting a broad spatial distribution and accumulation of perchlorate over Antarctica. Our aerosol measurements, combined with ice core data, support that an active origin for perchlorate may exist in the Antarctic troposphere due to the action of UV-radiation and the snowpack geochemistry interacting with sea salt. Using a microscopic/molecular speciation of individual aerosols by X-ray chemical imaging, it revealed a unique signal of ClxOy-type-molecules, reveling that Antarctica has undergone successive warming phases during interglacials that allowed the accumulation of salty crusts contain perchlorate.

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Organic content in Antarctica aerosols

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The organic contain on aerosols describes an interesting climate behavior and paint one of the significant fractions of tropospheric particles. We analyzed individual particles via microscopic and molecular speciation by Scanning Transmission X-ray microscopy with near edge X-ray absorption fine structure spectroscopy (STXM/NEXAFS). This method provided an accurate fraction of internally mixed inorganic and organic particles for an aerosol campaign of 2014 in West Antarctica (at Brazilian module, Criosfera 1). The results were revealing a lack of organic aerosol on Antarctica that could be driven by the oxidizing process during the transport of the coast to the sampling point. Oxidation reactions (primarily by the hydroxyl radical) of organic species can dramatically change the reactivity, amount, properties and hence the ultimate impacts of atmospheric particles, as the type of aging, with the potential to affect the optical properties, hygroscopicity, and cloud condensation nucleus activity of particulate matter. In Antarctica, photochemistry driven by locations with elevated levels of NOx results in the accumulation of tropospheric ozone that can double the background concentration. As a consequence of the high OH concentration above the snowpack (found at the South Pole) and by the ozone oxidation caused process, almost all organic aerosol found in our samples should be impacted and oxidized during the transport to the center of Antarctica. The organic suppression of organic matter observed at Antarctica aerosols can increase the water uptake of particles, reducing the Albedo effect, and impacting the local environment.

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Spatiotemporal variation of surface atmospheric 7Be from Australia to Syowa Station, and S17, Antarctica

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Deposition of atmospheric minor constituents on the ice sheet surface alters the radiation budget and creates climate markers in ice cores. Such minor constituents are not only of origin in the Antarctic but are also supplied by transport from distant sources. To clarify the mechanism of long-distance transport is to know the mechanism of climate change and to clarify the past atmospheric circulation. ^{7}Be is a radioactive element produced in stratosphere by cosmic ray, and the higher concentration of ^{7}Be implies higher contamination of stratospheric air.
This study measured the concentration of ^{7}Be on the Southern Ocean from Australia to Syowa Station on an island, Antarctica, and at S17 Station on the coastal Antarctic ice sheet during three summer seasons of December to January in 2014/15, 2016/17, and 2017/18. Few past studies discussed daily variation in concentration of ^{7}Be in Antarctica. Time series of the concentration of ^{7}Be shows the increases in the concentration as the latitude increase with the fluctuation from about 1 mBq/m^3 or less (the detection limit) to about 10 mBq/m^3. The latitude effect may be due to the descending flow in the polar vortex. The time-scale of the fluctuation is about a week or so, and tropopause folding associated with synoptic-scale disturbances may play a role.

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Neutron spectrometer operated in the Concordia station since 2015 and its contributions on Antarctica research activities

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The Earth is constantly bombarded by primary cosmic rays (CR) that can be either of galactic or solar origin. CRs concerns are interdisciplinary field, including impacts on human activities (electronics, biological effect) and applications such as archaeology, volcanology, geophysics or the cosmogenic nuclide dating. Moreover, Polar-region development induces an important issue related to space weather.
In the framework of the CHINSTRAP project supported by the French Polar Institute, a CR-induced-neutron spectrometer is operated since December 2015 in the inner Antarctic Plateau, at Concordia station. Several parameters can influence the CR measurement, the atmospheric pressure, the hydrometric environment and the atmospheric water vapor. These parameters were monitored in Concordia thanks to HAMSTRAD polar project which measure of the trends in water vapor and temperature profiles from the lower part of the troposphere to the lower part of the stratosphere. Then, atmospheric CR-shower modelling associated to a primary cosmic ray model allows for deducing a global secondary CR model. This allowed contributing to some scientific fields such as the dose ambient risk for polar workers, the cosmogenic nuclide dating activities, the development of solar flare paleo models or the space weather applied to electronic systems. This paper proposes to analyze four-year measurements from December 2015 to 2020, and to present CR contributions on Antarctica research activities, in the point of view of radiation characterization, human dose and cosmogenic nuclide dating. This work will also illustrate the importance of the neutron spectrometry in Antarctica for the development of an atmospheric-radiation global model.

1603

Wind filtering of mesospheric short-period gravity waves: Evidence revealed from all-sky images at King Sejong Station (62°S, 59°W)

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We have analyzed all-sky images observed with an OH airglow filter at King Sejong Station (62°S, 59°W), Antarctica for the period of 2012–2016. Using the M-transform method, 2D-power spectra were obtained from 107 image sequences. From the power spectral densities, it is evident that the mesospheric wave activity is the strongest during winter. We also constructed climatological wind blocking diagrams using the horizontal winds obtained from MERRA-2 reanalysis data for the altitudes of z = 10–64 km, and from KSS meteor radar data for z = 80–90 km. We find that the wind blocking diagrams clearly explain the dominant propagating directions of the observed short-period (< 1 hr) waves except for spring season. The strong south-eastward waves were observed in spring when wind blocking above z = 50 km are too weak for these waves, suggesting that the mesospheric waves may be generated above ~50 km.

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Propagation And Sources of the Short Period Gravity Waves over Syowa Station (69S, 40E) and Davis station(69S, 78E) Studied by Airglow Imaging in 2016

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We recently compared the gravity waves over Syowa and Davis, which have similar terrain and meteorological conditions, to show their horizontal variation over the East Antarctic. Propagation characteristics are observed by airglow imaging measurements of 90 km altitude. The comparison in April-May 2013 have indicated that the major propagation directions were westward at Syowa, but at Davis, GWs seems to propagate in all the directions [Matsuda et al., 2017]. The goal of this study is to reveal what causes the difference in the gravity wave characteristic over Syowa and Davis. Ground-based horizontal phase speed spectra at 87 km altitude over the two stations were derived from OH imagers in more detail. The mean spectra were then calculated in winter (May to August) and fall (September). The winter means spectra and directionality are similar. The comparison with transmission diagrams [Tomikawa, 2015] showed that the phase velocity regions of turning and critical level filterings are almost same at both stations. The variance of the gravity wave perturbations was very similar both in magnitude and seasonal variations (maximum in winter), except for September/October. In September, directionalities are similar at both stations but power in Syowa is much larger than that in Davis. The phase velocity spectra are also calculated for 6 different period band in 8 – 60 min. We found that peaks of the phase velocity spectra for period bands smaller than 11 min were located at prohibited propagation areas. This suggests that such high-frequency gravity waves were generated in the mesosphere.

1189

Satellit observation of secondary gravity waves over the Southern Andes during an intense mountain wave event

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The Southern Andes are well known as one of the mountain wave hot spots. Recently, Vadas and Becker [2019] demonstrated with numerical modeling that the breaking of mountain waves over the Andes can create secondary GWs at about 50-80 km of altitude, yielding concentric ring structures. Some observational studies support this hypothesis [e.g., Liu et al., 2019], but the observational evidence is still limited and indirect, and the characteristics of the secondary GWs are not well understood. The purpose of this study is to look for signatures of secondary GW generation in observations from a space-based instrument (VIIRS/Suomi-NPP) and compare their characteristics in the real atmosphere with model simulations.

This study focuses on a mountain wave event with significant amplitudes (>3 K) and ~500 km horizontal wavelengths over the Southern Andes, observed on 24 and 25 July 2017 with AIRS/Aqua satellite data [Hoffman et al., 2017]. VIIRS/Suomi-NPP (can resolve GWs with > several km horizontal wavelengths at ~85 km) did not detect mountain waves but instead observed concentric ring-like GWs with a few hundred km wavelengths at 4.5 UT on the same night (25 July 2017) over the Southern Andes and its east side.

We will show the observational results and discuss the relationship between the mountain waves observed and the concentric GWs. In particular, we will focus on what altitude the observed mountain waves broke and why the observed concentric ring-like GWs extended leeward.

1140

Application of tritium tracer technique to the partitioning between clear-sky and synoptic precipitation on the Antarctic plateau

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In Antarctic plateau, precipitation falling from clear sky (known as diamond dust) occurs almost daily, but a few major synoptic events can give a significant fraction of the annual accumulation. Thus, it is not clear how much contribution of clear-sky precipitation to the total accumulation on the plateau. Here we introduce alternative method for partitioning between synoptic and clear-sky precipitation: tritiated water (HTO). Tritium (T) is one of the cosmogenic nuclides, which mainly produce in the upper atmosphere over the Antarctica. After the HTO generation, HTO follows the pathway through hydrological cycle, with only small perturbations owing to fractionation effect during phase changes. Consequently, HTO concentrations in diamond dust formed by condensation of local Antarctic water are characterized by higher HTO than the synoptic precipitation accompanied with moisture transported from the surrounding ocean. We analyzed HTO in surface Antarctic snow collected by repeated traverses between Syowa and Dome Fuji and found two prominent spatial features; the gradual increase trend from the coast to plateau region and the rapid increase in HTO toward inland on the plateau. In addition, a good anticorrelation is observed between HTO and $\delta^{18}O$ of snow on the plateau. These features indicate that much of the plateau accumulation results from clear-sky precipitation with no synoptic-scale moisture transport. To support this interpretation, here we use the atmospheric circulation model incorporated into HTO and show that the balance between clear-sky and synoptic precipitation is a key driver controls HTO distribution on the Antarctic plateau.

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Local, distant and cosmogenic sources of dust from the glaciers of Svalbard

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The glaciers of Svalbard are an excellent repository of aeolian dust. In order to determine provenance of such dust as locally or globally derived, we examined particulates collected in shallow (0.5-1m long) firn cores from the glaciers of Southern Spitsbergen: Hansbreen, Storbreen, Flatbreen, Recherchebreen and Werenskioldbreen. Various minerals were identified, including pyrite, iron oxides, quartz, K-feldspar and rutile. Iron oxides are predominantly magnetite and no hematite is present, as it would be expected from subtropical/moderate climate sources. This supports high-latitude provenance for the dust. Coarser grains probably stem from proximal areas, whereas finer grains may have been transported from more distal sources. Particulates composed of elemental carbon have been found in a number of specimens; although their origin is still unknown they may be derived from anthropogenic sources or from forest fires. An alloy of Ni+Fe composition may be a micrometeorite grain. Zircon and monazite are also present, with grains of the latter being large enough for electron microprobe dating. These reveals mostly Silurian (syn-Caledonian) ages, which are also found in bedrock of the Nordaustlandet region of Svalbard. One grain was ca. 1.3 Ga and may be derived from basement rocks. We suppose that eroded Svalbard mountain ranges are a major source of dust, which is deposited on and preserved in the local glaciers. However, there are evidence for all kind of sources and future studies are planned on dust distribution, anthropogenic dust contamination and potential cosmogenic sources over Svalbard.

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Measuring Precipitation and Sublimation Rates on the Ross Ice Shelf

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A two-year collaboration between the University of Colorado (CU)-Boulder and the National Center for Atmospheric Research (NCAR) studied precipitation measurements gathered from four locations on the Ross Ice Shelf in Antarctica from November 2017 to November 2019. These year-round measurements were made possible by funding from the United States Antarctic Program (USAP). An autonomous precipitation measurement system was developed to withstand extreme weather conditions while drawing very little power to record measurements. The precipitation measurement system utilized a combination of sensors including an OTT Pluvio2 weighing precipitation gauge nested inside a double Alter-style wind shield, a snow-height sensor, solar-radiation sensors, a wind-speed sensor, particle counters, and disdrometers. Web cameras were also used to record periods of precipitation and distinguish between blowing, versus falling, snow. Although the primary goals of the project were focused on collecting accurate measurements of precipitation in the Antarctic region, broadening the body of knowledge of the surface mass balance, and assessing numerical model precipitation estimates, it was also discovered that sublimation could be measured by the same system. Based on initial observations of both precipitation and sublimation amounts from the precipitation gauge, a new methodology was developed to derive accurate precipitation and sublimation rates. A high-level overview of the project will be presented with a focus on the results of this work, including precipitation and sublimation rates, and comparisons of measured snowfall amounts to model-predicted accumulations.

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Measuring elemental composition and number of individual mineral nano- and micro-particles in ancient Antarctic ice cores by single particle inductively coupled plasma mass spectrometry

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To date, there is no comprehensive Antarctic study of the elemental composition of individual atmospheric nano- and micro-particles and the number concentration with each composition despite the role that they play in climactic processes (i.e. influencing planetary albedo by reflecting and scattering radiation, absorbing radiation, or acting as nuclei for ice and clouds). Previously the average elemental composition of atmospheric mineral particles entrapped in Antarctic ice has been obtained by dissolving the particles and determining trace elements in the bulk solution by inductively coupled plasma sector field mass spectrometry (ICP-SFMS). We measured the elemental chemical composition of thousands of individual mineral particles by single particle inductively coupled plasma mass spectrometry (spICP-MS). We will briefly describe how spICP-MS works. Two different instruments were used: ICP-Quadrupole MS (ICP-QMS) which measures one isotope at a time and ICP-Time of Flight MS (ICP-TOFMS) which acquires a complete elemental mass spectrum for every particle. Particles in the horizontal ice core from Taylor Glacier (East Antarctica) spanning part of the last glacial-interglacial cycle (9-44 kyr BP) have been analyzed by spICP-QMS and spICP-TOFMS. Our primary goal is to determine if and how the number concentration and elemental composition of individual atmospheric mineral particles have changed over time.

1120

The Joint US NSF-DOE Atmospheric Radiation Measurement (ARM) Program West Antarctic Radiation Experiment (AWARE)

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AWARE was a year-long atmospheric and climate science field program on Ross Island that deployed many of the most advanced meteorological and remote sensing instruments currently available. The suite of instruments included with the Second ARM Mobile Facility (AMF2) included research radars in the Ka-, W- and X-bands, high spectral resolution and micropulse lidars, microwave radiometers for water vapor and cloud liquid water content, broadband and spectral radiometers in the shortwave and longwave, and equipment for measuring aerosol microphysics and chemistry. The AMF2 operated on Ross Island from December 2015 through December 2016, and a smaller instrument suite optimized for surface energy balance measurement operated at the WAIS Divide Ice Camp in West Antarctica during December 2015 and January 2016. AWARE data reveal unique properties of the Antarctic troposphere that provide stringent case studies for cloud microphysical evaluation in climate models, including supercooled liquid water at lower temperatures than found in the high Arctic troposphere, and influence from gravity waves. The aerosol observation suite provides an annual cycle of aerosol properties showing chemical and microphysical contrasts with comparable high Arctic data. Triple-frequency cloud scanning radar observations from AWARE are the first of their kind in Antarctica, and can differentiate between various modes of cloud ice water including small crystals, rimed particles and large aggregates. This presentation discusses these varied observational cases and their incorporation into climate model evaluation. AWARE data are fully available to the worldwide research community in the ARM Program archive, which provides efficient data search and access.

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Evaluation of Blowing Snow Impacts on the Low Atmosphere and Surface for A Severe Cyclone System over Antarctic Peninsula using WRF-ice Model

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To better capture the air-snow-ice interaction, a snow/ice enhanced Weather Research and Forecasting (WRF-ice) model has been developed. This study examines the overall performances of WRF-ice and its blowing snow component with a mesoscale cyclone that occurred during 23-26 October 2017 over the Antarctic Peninsula. The evolution of the mesoscale cyclone is well reproduced by WRF-ice and the simulated surface temperatures reasonably agree with satellite observations, with root-mean-square errors and bias scores for surface temperatures of land-ice (sea-ice) of 3.55 and 0.3 K (3.11 and 0.23 K) during the daytime, respectively.
Comparisons between control simulation and a sensitivity simulation with blowing snow processes suppressed show that blowing snow sublimation is prominent within lower atmosphere when the air is dry and clear, and accordingly moistens and cools the air. Over relatively warm humid areas, enhanced clouds by blowing snow lead to either colder or warmer surface, as the surface temperature depends on the competing effects of longwave and shortwave cloud radiative forcings (CRF). Additional moisture from blowing snow sublimation can slightly intensify precipitation over the mountain. Surface energy budget analyses indicate that downward shortwave (Sa) and longwave (Ld) CRF, and outgoing longwave CRF (Lu) are dominant surface heat fluxes components. Combined with increased sensible heat flux, Ld, Lu, and decreased Sa, latent heat flux due to blowing snow, a negative surface net heat flux occurs during the daytime. As a consequence of increased precipitation, reduced runoff and sublimation, a positive domain-total surface mass balance (~5 Ton) is generated during the cyclone.

1417

Recent observations of clouds and their radiative effect over the Southern Ocean.

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Clouds over the Southern Ocean are poorly simulated in climate models (Trenberth and Fasullo, 2010; Hyder et al., 2018), leading to a net bias in the amount of radiation arriving into the ocean (Bodas-Salcedo et al., 2013). Our knowledge of the different contributions of meteorological and aerosol influences, and how these vary spatially and temporally, is still limited in this region.

We use recent cloud, aerosol and meteorological observations in the Southern Ocean to try and improve our understanding of these processes that govern the cloud radiative effect. These observations include 200 days of ship-based measurements across three campaigns between 2016 and 2018, as well as 2 years of measurements at Macquarie Island over the same period.

Using these observations, in combination with the reanalysis data and satellite measurements, we use gradient boosted regression to model the cloud radiative effect and isolate the influence of the contributing factors. This methodology will be extended to better understand biases in the cloud radiative effect in the Australian Community Climate and Earth System Simulator (ACCESS) model and highlight the paramaterisations that need improvement.

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Solar activity reflection in ozone vertical distribution over Antarctica

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Zonal average monthly Solar Backscatter Ultraviolet Radiometer (SBUV) satellite data have been used to study the vertical ozone distribution in 1979–2018. The quasi-11-year period solar activity cycle from the ozone data series was investigated with the wavelet transform. Solar activity was characterized by sunspot numbers and F10.7 solar radio flux data. Wavelet power spectra were calculated for periods of 1–24 years. Zonal ozone distribution in the high southern latitudes was studied as well. We have considered SBUV ozone profiles over the Antarctic stations Vernadsky and Casey located in the opposite longitudinal sectors. It is shown that quasi-11-year disturbances in the ozone distribution were observed at lower altitudes over Vernadsky (22–31 km) than over Casey (31–37 km). Vernadsky located during spring in the edge region of the ozone hole where ozone is significantly destroyed near its typical maximum in its vertical profile with penetration of ultraviolet radiation to the lower heights. The solar activity influence is non-uniform to a considerable degree. The periods close to 11 years are the most noticeable (i) in the equatorial lower stratosphere, (ii) in the summer upper stratosphere of the high latitudes, (iii) in the middle-upper stratosphere of the southern hemisphere in distinction on the northern one. The zonal asymmetry between solar activity manifestations in the stratosphere over West and East Antarctica was noticed.

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Utilising Radiosonde Observations Around Antarctica: Studying Stratospheric Gravity Waves

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Regular radiosonde launches occur at many Antarctic bases and on scientific ship cruises as part of their associated metrological programmes. These radiosonde observations can be used to study atmospheric gravity wave properties.

The UK funded DRagon pAssaGe and sOuthern oceaN Wave Experiment (DRAGON-WEX) aims to use a range of instrumentation and modelling to determine the sources of gravity waves close to 60°S, to try and determine where the “missing momentum flux” that is present in atmospheric models is coming from.

As part of DRAGON-WEX we present the results of the preliminary analysis of stratospheric gravity waves observed using radiosondes from around Antarctica. This work also aligns with the aims of the ANtarctic Gravity Wave Instrument Network (ANGWIN).

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Quasi 10- and 16-day planetary waves in the MLT winds at Ferraz station, Antarctica

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The meteor radar has been used to measure winds in the mesosphere and lower thermosphere region at Ferraz station (62.1S, 58.4W) Antarctica. Winds obtained from February 2011 to mid-February 2012 were analyzed and results reveal the presence of oscillations with periods around 10 and 16 days from late autumn to late spring, which has been interpreted as planetary waves. The characteristics of these planetary waves identified over Ferraz station will be discussed and presented in this work. In addition, MERRA reanalysis data from stratosphere and VLF signals obtained by receivers at Ferraz station are used to study possible stratosphere-mesosphere coupling by planetary waves including the lower ionosphere region.

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Antarctic gravity-wave activity in the mesosphere and lower thermosphere as measured with radars in the ANGWIN network

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Atmospheric gravity waves play an important role in transporting energy and momentum vertically through the atmosphere, and drive circulations that affect key processes such as formation of the ozone hole and the cold summer polar mesosphere. The lack of comprehensive observations over the Antarctic region has an impact on our understanding of these processes. The ANtarctic Gravity Wave Instrument Network (ANGWIN) seeks to use a network of observations to measure gravity waves continent wide and through all levels of the atmosphere, in order to fully understand their impact and to constrain their parameterization in models.

Atmospheric radars are one of the instruments included in the ANGWIN network. Meteor radars detect meteor trails at heights in the mesosphere and lower thermosphere and track them to build estimates of wind speed. Medium frequency radars carry out a similar task by tracking the patterns of radio reflections from turbulent structures.

This presentation will describe the application of common gravity-wave analysis techniques to the different types of radars at our various Antarctic sites. Access to co-located radars provides insights into the potential effects of the radar wind determination method on our analysis and allows a continent wide comparison to be made. The characteristics of gravity waves at the radar sites are then determined through a common observation year (2016).

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ANGWIN: ANtarctic Gravity Wave Instrument Network

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Atmospheric gravity waves play an important role in transporting energy and momentum between atmospheric spheres and drive circulations that affect key processes such as formation of the ozone hole and the cold summer polar mesosphere. The lack of comprehensive observations over the Antarctic region has an impact on our understanding of these processes. The ANtarctic Gravity Wave Instrument Network (ANGWIN) is a highly successful grassroots programme that was started in 2011. It seeks to use a network of observations to measure gravity waves continent wide and through all levels of the atmosphere, in order to fully understand their impact and to constrain modelling work. Although ANGWIN initially focused on the Antarctic, the group is now aiming to develop collaborations in both polar regions.

Current member countries of ANGWIN are Australia, Brazil, Japan, South Korea, the United Kingdom and the United States of America. The objective of ANGWIN network include; Qualify the longitudinal variations in gravity waves and determine causes; Characterize wave propagation and influence; Relate observed gravity waves to sources throughout the atmosphere; Study interactions of gravity waves with planetary scale waves; Compare polar wave observations to model parameterizations; Determine the effects of gravity waves on polar stratospheric cloud formation.

The ANGWIN network, its objectives and some recent results will be included in this presentation.

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Supercooled Liquid Water Cloud observed, analysed and modelled at the Top of the Planetary Boundary Layer above Dome C, Antarctica

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A comprehensive analysis of the water budget over the Dome C (Concordia, Antarctica) station has been performed during the austral summer 2018-2019 as part of the YOPP international campaign. Thin (~100-m deep) supercooled liquid water (SLW) clouds have been detected and analysed using remotely sensed observations, at the station (LIDAR, microwave radiometer HAMSTRAD, net surface radiation from BSRN, radiosondes) and on satellite (CALIOP LIDAR) combined with a specific configuration of the NWP model ARPEGE-SH. Two case studies are used to illustrate this phenomenon. On 24 December 2018, the atmospheric planetary boundary layer (PBL) evolved following a typical diurnal variation, which is to say with a warm and dry mixing layer at local noon thicker than the cold and dry stable layer at local midnight. Our study showed that the SLW clouds were observed at the top of the PBL. The second case study takes place on 20 December 2018, when a warm and wet episode impacted the PBL with no clear diurnal cycle of the PBL top. The amount of liquid water measured by HAMSTRAD was ~20 times greater in this perturbed PBL than in the typical PBL. In both cases, ARPEGE-SH was not able to accurately reproduce these SLW clouds, and the discrepancy between the observed and calculated net surface radiation was reaching +50 W m-2. The model was then run with a new liquid water partition function and was able to generate SLW clouds on 24 December 2018.

1452

Precising dust provenience in Western Antarctica by the integration among Sr-Nd isotopic signatures in fresh snow, remote sensing and atmospheric modeling

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Eolian dust is widely accredited as an important player to climate and environmental change, Nevertheless, gaps in the knowledge of determining their provenance still exist. We present here a method which objective is to improve the determination of dust sources based on the combination of 3 parameters: (1) the radiogenic isotope signal of the fresh snow conducted at the Brazilian Antarctic remote laboratory, Criosfera1 (84°S, 79°W); (2) the dust activity of the postulated sources (using aerosol index); (3) the air mass trajectory frequencies linking the site in Antarctica and the postulated sources. The backward air mass trajectories derived from the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT), cannot alone guarantee the origin of aerosols due to model limitations and extrapolations to the polar region, additionally, the radiogenic signal can be quite similar at sites from different continents as South America, Africa, and Australia depending on the geological formation. Finally, the Aerosol index, product from the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY), can be a decisive component in the interpretation of provenance. For the present work, we present an integrated measurement of isotopic ratios for Sr and Nd of snow deposited during a 5 month integration (August to December 2013) and 3 months integration (October to December 2015) obtaining the values 0,709929 <87Sr/86Sr <0,729392 and -33,7 < ƐNd <-14,6 as well as the corresponding trajectory frequencies and aerosol index. Our results point to the importance of the combined use of the above parameters to the accuracy in identifying dust provenance.

1321

In Situ Precipitation Observations for the Northwest Ross Ice Shelf, Antarctica: A Review of the Instrument Systems and Analysis of the Observations

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Four low-power, autonomous Antarctic Precipitation Systems (APSs) were installed on the Ross Ice Shelf, Antarctica for year-round in situ measurement of precipitation. The APS sites were installed for two years, starting in November 2017, as a part of the United States Antarctic Program (USAP). The liquid-water-equivalent precipitation was measured using an Ott Pluvio2 weighing precipitation gauge installed inside a double-alter wind shield. Additional measurements, such as snow height, wind speed, particle counts, and videos, were included in the APS sites to provide supporting observations. The precipitation measurements, and supporting observations, are providing a “ground truth” in understanding precipitation and snow accumulation in Antarctica. A review of the instrument systems will be provided, including an assessment of the successes and lessons learned during the two-year field deployment. The presentation will also include analyses of precipitation events and a comparison across the different instruments. Analyses will also be provided by studying event-by-event accumulation of precipitation at the four sites in comparison to the numerical model results of liquid-water-equivalent precipitation. The results will provide insights on the capability and validity of in situ precipitation observations for assessing numerical models and future capabilities in the measurement of precipitation.

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Investigation of Black Carbon aerosols over the Antarctic region using a regional climate model

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Aerosols and their interaction with sea, cryosphere and clouds can have crucial impact on radiation balance over the Polar region. They absorb and scatter incoming solar and outgoing terrestrial radiation to a different extent depending on their concentrations, types and size. They can also modify the cloud properties (lifetime and scattering properties) by acting as cloud condensation nuclei. Black Carbon (BC) (which is generated by biomass and fossil fuel burning) can trap radiation and warm the atmosphere; and are reported to be the second strongest contributor to global warming after carbon dioxide. The simulations of Weather Research and Forecasting model coupled with Chemistry (WRF-CHEM) were investigated and compared with the aerosol observations over the East Antarctic region. The model simulations were performed at horizontal grid resolution of 50 km × 50 km. The 6-h initial and lateral boundary conditions for the meteorological fields from National Centre for Environmental Predictions, Final Analysis (NCEP/FNL) were utilized in the simulations. The chemical mechanism for gas-phase chemistry in WRF-CHEM simulations was provided from MOZART4 and for aerosol process based on Goddard Chemistry Aerosol Radiation and Transport (GOCART) bulk aerosol scheme (MOZCART). BC mass concentration was found to higher over the Eastern Antarctic region during the forest fire seasons in Australia. This may be due to transport of BC produced by biomass burning. The detailed results on spatial and seasonal variations of BC over the Antarctic and surrounding regions will be presented and discussed.

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Snow surface pattern observations along traverse routes between Showa Station and Dome-Fuji Station of Antarctica using camera images

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Snow surface patterns in Antarctica are of practical concern and are important for assessing the surface mass balance of the ice sheet. Snow depth measurements between Syowa Station and Dome Fuji Station using snow stakes at 2 km intervals have been carried out by the Japanese Antarctic Research Expedition at the time of a traverse as part of a monitoring program. It is not clear how the snow depth changes seasonally. In this study, we have carried out snow surface pattern observations indicating erosion and deposition to grasp the actual situation of the snow surface. Firstly, to obtain the image of the snow surface state, an interval camera was installed in a snow vehicle making a round-trip traverse between the coast and the inland in summer of 2017. Secondly, to obtain the seasonal variation of the snow surface state, four interval cameras were installed at selected points along a latitudinal transection between the coast and the inland in summer of 2017. Snow surface patterns were classified in three kinds by sight. Analyzed results of altitude dependence of the snow surface patterns fairly agreed with a previous research. However, a difference was confirmed in altitude dependence of large sastrugi formation in comparison with the previous research. This presentation describes the progress of the snow surface observations using camera images and also discusses extracted problems.

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Ground-based measurements of total ozone column amount with a multichannel moderate-bandwidth filter instrument at the Troll research station, Antarctica

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Combining information from several channels of the Norwegian Institute for Air Research (NILU-UV) irradiance meter, one may determine the total ozone column (TOC) amount. A NILU-UV instrument has been deployed and operated on two locations at Troll research station in Jutulsessen, Queen Maud Land, Antarctica, for several years. The method used to determine the TOC amount would be presented, and the derived TOC values are compared with those obtained from the Ozone Monitoring Instrument (OMI) located on NASA's AURA satellite. The findings show that the NILU-UV TOC amounts correlate well with the results of the OMI and that the NILU-UV instruments are suitable for monitoring the long-term change and development of the ozone hole. Because of the large footprint of OMI, NILU-UV is a more suitable instrument for local measurements.

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LODEWAVE: LOng-Duration balloon Experiment of gravity WAVE over Antarctica

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Super-pressure balloons (SPBs) can float at a constant density surface in the troposphere and stratosphere for long duration (i.e., several months). They can follow Lagrangian motions of air parcels, which is beneficial for gravity wave studies. Gravity waves are one of uncertain factors in current climate models, in which it is required to obtain their stochastic features as well as their spatial and temporal mean behavior. SPBs enable us to obtain stochastic features of gravity waves in a full frequency range from Brunt-Vaisala frequency to inertial frequency. On the other hand, the PANSY radar, which is only MST/IS radar in the Antarctic, has been operated at Syowa Station since 2012. It measures three-dimensional winds with high temporal and vertical resolution and can obtain stochastic features of gravity waves in a full frequency range. It is expected to obtain three-dimensional gravity wave features in the Antarctic by combining SPB and PANSY observations. Thus, our group proposes new SPB observations in the Antarctic.

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Characteristics of Marine Boundary Layer Clouds over the Southern Ocean

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Marine boundary layer (MBL) clouds over the Southern Ocean (SO) remain poorly understood due, primarily, to sparse observations. It has been hypothesized that this poor understanding directly contributes to persistent large biases found in the radiation budget over the SO in both climate models and reanalysis products. Motivated by the need to improve the understanding of key atmospheric processes of the SO climate system, a range of field campaigns have taken place in recent years (e.g. CAPRICORN, SOCRATES, MARCUS and MICRE), yielding an unprecedented wealth of measurements ranging from Hobart to the edge of Antarctica. In total, 2186 soundings are employed to map out characteristics of the ABL and their clouds over the SO.

The analysis explores variations in the MBL characteristics in relation to the sea surface temperature (SST) and synoptic meteorology (e.g. distance to fronts/cyclone). The analysis further examines the macroscopic properties for clouds between 0.5 and 4km altitude. The cluster analysis were readily sorted by the underlying SST leading to a warm cluster, four storm-track clusters and two cold-ocean clusters. The four storm-track clusters can, to first order, be approximated by the classic Norwegian model of mid-latitude cyclones. The warm cluster commonly characterises an air mass off the Australian continent. The two cold-ocean clusters are found to be highly distinct. The coldest cluster, commonly found at the coast of Antarctica, is often cloud-free, while the soundings primarily located off the coast commonly have multiple cloud layers and a complex thermodynamic structure.

Keywords: MBL, multi-layer clouds

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Simulating the contribution of marine organic carbon to Southern Ocean aerosol and clouds

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The marine aerosol burden is often described as being dominated by sea salt and sulfate. However, observations and laboratory studies have highlighted a significant contribution to marine aerosol from emission of organic carbon. Despite this, even the latest generation of aerosol schemes included in climate models neglect organic carbon emissions, introducing potential biases to the simulated clouds, precipitation, and radiative budget.

Marine organic carbon emissions can be primary (direct release of organic carbon in particles) or secondary (organic carbon emitted in the gas-phase). The lifetime and fate of aerosol from the two distinct source mechanisms are quite different, and require individual representation in an aerosol scheme to quantify their role in the climate system.

We have used the ACCESS-UKCA composition-climate model (which includes the GLOMAP-mode aerosol microphysics scheme) to simulate the emission and fate of primary and secondary organic carbon. We compare the model against observations made during the Surface Ocean Aerosol Production (SOAP) ship campaign in the productive seas east of New Zealand, and also against long-term observations from fixed stations (e.g. Cape Grim). We quantify the contribution marine organic carbon makes to Southern Ocean aerosol mass and number, and the subsequent impacts on cloud optical properties and radiation. Including emissions of marine organic carbon can reduce the Southern Ocean radiation bias, and opens the door to including paramterisations of ice nuclei number concentration.

1223

Comparison of wind frequency spectra over Syowa Station between the ERA5 reanalysis and the PANSY radar

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The latest objective and reanalysis data have horizontal resolution fine enough to partially resolve gravity waves (GWs), which enable us to estimate their momentum flux and energy. It is reported that the European Centre for Medium-Range Weather Forecasts (ECMWF) operational analysis reproduced the horizontal distribution of momentum flux due to GWs, which was similar to but smaller than the observations by a factor of 3-5.
In this research, we evaluate how much GWs over Syowa Station (39.6E, 69.0S) are reproduced in the ERA5 reanalysis data by comparison with the PANSY radar observation. The ERA5 reanalysis is the latest meteorological reanalysis dataset provided by the ECMWF. The PANSY radar at Syowa Station is the only Mesosphere-Stratosphere-Troposphere/Incoherent Scatter (MST/IS) radar in the Antarctic and can observe GWs in all frequency bands and estimate their momentum flux in the troposphere and lower stratosphere. We compared frequency spectra of three-dimensional winds between the ERA5 reanalysis and the PANSY radar from January to March 2016. While the frequency spectra of horizontal winds showed a good agreement between ERA5 and PANSY in a frequency range lower than the inertial frequency, those of ERA5 were smaller than those of PANSY in a frequency range higher than the inertial frequency. Also, we found that the frequency spectra of vertical wind in ERA5 were smaller than those of PANSY in all frequency bands. We will discuss why such a difference between ERA5, and PANSY appears especially in the vertical wind.

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Modeling the Lower Atmosphere and Surface Mass Balance of Antarctic Peninsula Ice Sheet with a Snow-Ice Enhanced WRF-ice Model

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Antarctic Peninsula (AP) is among the most rapidly changing regions in the world , which makes it an ideal target for developing a model framework suitable for understanding the climate change impacts on the ice sheets/shelves. As thus a snow/ice enhanced Weather Research and Forecasting model WRF-ice has been developed. This study examines the overall performances of WRF-ice and its blowing snow component with a case study of mesoscale cyclone during October 23-26 2017 over AP. WRF-ice simulated surface temperatures over ice sheet, ice shelf and sea ice are in reasonably good agreement with the MODIS surface temperatures. Blowing snow effects in the WRF-ice simulation show that water vapor in the lower atmosphere increases owing to the blowing snow sublimation, and more clouds and precipitation are generated when enough moisture and lifting are present. Blowing snow sublimation is prominent when the air is dry and clear, and accordingly moistens and cools the air. Over relatively warm and humid areas, enhanced clouds by blowing snow lead to either colder or warmer air and surface temperatures depending on the competing effects of longwave and shortwave cloud radiative forcings (CRF). Additional moisture from blowing snow sublimation can intensify precipitation over the mountain areas. Furthermore, surface energy budget indicates decreased (increased) latent (sensible) heat flux due to blowing snow. Combined with increased (decreased) longwave (shortwave) CRF, a negative surface net heat flux occurs during daytime. As a consequence of increased precipitation and reduced runoff and sublimation, a more positive surface mass balance is generated.

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SESSION 3

ANTCLIM21 AND BEYOND:
FUTURE ANTARCTIC CLIMATE CHANGE ON DECADAL TO CENTENNIAL TIMESCALES

Nancy Bertler
Lettie Roach, Tom Bracegirdle

1676

Stability of soil organic matter in ornithogenic soils of the Maritime Antarctica

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Climate change in the polar regions has been described as very dramatic in recent decades. Better understanding and modeling the Earth´s climate system requires improving our knowledge of carbon, water and energy exchange between terrestrial ecosystems and the atmosphere (IPCC, 2007). In severe climatic conditions of Antarctica birds play an important role in transportation of organic matter to the coastal landscapes. This study is aimed at studying structural and molecular composition of organic matter in soils of King George and Ardley islands (South Shetland Islands). We revealed that redistribution of guano components significantly affects the speed of soil cover spatial development and formation of new polypedons. We found that the humic acids (HAs) of the cryoturbated, buried areas had lower amounts of alkyl aromatic and protonized aromatic compounds. In contrast, the HAs from the surface layers contain less alkyl carbon components. Our data showed that the portion of aromatic compounds is little higher in soils under materials transported by birds compared to soils developed under bryophyta or lichens communities. This is probably because birds use mainly remnants of Deschampsia antarctica (with high portion of phenyl-propanoic organic precursors) for nest building. Comparison of the 13C-NMR spectra of the HAs and the bulk SOM revealed that humification occurs in the Antarctic and results in accumulation of aromatic and carboxylic compounds and reductions in alkylic ones. This indicates that humification is one of the ways of soil organic matter stabilization.

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Understanding the response of the Amundsen Sea Embayment to century-scale ocean forcing

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Projections of the 21st century Antarctic sea level contribution are uncertain. Much of this uncertainty is associated with the mass loss from the Amundsen Sea Embayment (ASE), a catchment that has experienced considerable mass loss and grounding line retreat in recent decades. Ocean forced basal melting, controlled by wind driven transport of warm Circumpolar Deep Water (CDW) toward ice shelf cavities, is responsible for the observed thinning and speed up of ASE glaciers. The delivery of CDW toward grounding lines of ASE ice streams is projected to increase over the 21st century, driving high melting and grounding line retreat. Here we present a series of idealised experiments of 21st century basal melting applied to a regional set up of the ASE. We use the BISICLES ice sheet model which uses adaptive mesh refinement to model grounding line position at high resolution (250 m). The sensitivity experiments are forced with a series of linear increases in the applied sub-ice shelf melting which are then removed at varying intervals to show the dynamic response of the system in the absence of forcing. We repeat these experiments but with a removal of forcing, allowing the grounding line to advance. The results provide an indication of whether advance of the grounding line is plausible after substantial ocean forcing and, if so, what magnitude of ocean cooling is necessary for the ASE ice streams to recover.

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Drivers of Antarctic Intermediate and Mode Water export in CMIP models

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The subduction rates in the circumpolar region are responsible for the formation of the Subantarctic Mode Water and Intermediate Antarctic Water in the Southern Ocean, which consist as part of the upper branch of the meridional overturning circulation, highly important in the global climate system. Theoretical understanding predicts these waters masses are driven by wind stress curl and buoyancy fluxes. The objective of this work is to evaluate how much of AAIW and SAMW variability in CMIP solutions (generation 5 and 6) is correlated to Southern Ocean fluxes. We compare AAIW and SAMW volume transport at 30oS with Ekman Pumping, Freshwater and Heat Fluxes through a Multivariate Regression procedure. We found a significantly variability of mean transport of the water masses between CMIP models. Initially, was test temporal lags were tested individually for each parameter in the analysis and resulted in a better correlation with no lags for Ekman Puming, 2 months for Freshwater fluxes and 3 months for Heat fluxes. The multivariate analysis showed that AAIW and SAMW are significantly correlated to fluxes in most models, with few exceptions. Heat fluxes is the dominant forcing to explain variability of AAIW, while the export of SAMW was best explained by a combination of Ekman Pumping and buoyancy fluxes. Correlation coefficients in most models are consistent with theoretical expectations, with a positive (negative) relationship with Ekman Pumping (buoyancy fluxes).

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Evaluation of the representation of the Antarctic continental shelf seas in climate models

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The Antarctic Continental Shelf Seas are a critical, rapidly-changing, element of the Earth system. Evaluation of the representation of the Antarctic continental shelf seas across CMIP6 models is critical: regional water mass properties are used to drive sea level projections from the Antarctic ice sheet, and previous CMIP ensembles show substantial biases with a wide inter-model and inter-region spread. However, the Antarctic continental shelf seas remain sparsely sampled, posing challenges for model-data comparison.

This study aims to evaluate and compare climate model performance on the Antarctic continental shelf. In particular, we showcase a new cluster-based, grid-independent, methodology to identify and compare regional water masses. Applied to WOA18, this method identifies various regimes on the shelf, such as regions of high salinity shelf water formation, and regions of mixed water masses. Preliminary work with CESM demonstrates that this method can identify the location of distinct shelf regimes independently of the mean-state model bias. This method will be used in conjunction to more traditional water masses characterization to evaluate CMIP6 models.

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Rapid Ross Sea Deglaciation as captured in the RICE Ice Core

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The Roosevelt Island Climate Evolution (RICE) project recovered a 763.4 m deep ice core to bedrock from Roosevelt Island, at the northern edge of the Ross Ice Shelf. The ice at Roosevelt Island is grounded 210m below sea level and accumulates in situ, with the Ross Ice Shelf flowing around the rise.
Comparison of the modern RICE isotope data with meteorological records from weather stations and reanalysis products suggest that the record is representative of the temperature variability in the Ross Sea Region, the Ross Ice Shelf and western West Antarctica. In addition, the analysis shows that the RICE record is particularly sensitive to changes in regional sea ice extent and low and mid latitude climate drivers, in particular to the combined effects of the El Niño Southern Oscillation, the Pacific Decadal Oscillation and the Southern Annular Mode.
Here, we show isotope and geochemical data spanning the past 68 ka. Our data suggest that the Ross Ice Shelf grounding line retreat during the last deglaciation was driven at least in part by the early onset of deglaciation in West Antarctica as recorded in the WAIS Divide ice core (WDC). The Ross Ice Shelf grounding line started to retreat rapidly with the initiation of an ice shelf cavity. Atmospheric circulation changes precede the onset of the Antarctic Cold Reversal (ACR) by about 200 years. We observe that RICE leads the WDC onset of the ACR by about 300 years.

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Twenty first century changes in Antarctic and Southern Ocean surface climate in CMIP6

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Reliable estimates of Antarctic climate system responses under a range of future climate forcing scenarios are a high priority since, for example, ecosystems and ice shelves are highly sensitive to the timing of crossing of key thresholds in regional conditions. In the presentation results from an assessment of absolute and global-relative 21st century projections will be shown for a wide range of climate forcing scenarios based on output from the latest generation of state-of-the-art climate models participating in the new Coupled Model Intercomparison Project Phase 6 (CMIP6). Firstly an overview will be given of the main broad-scale 21st century Antarctic projections provided by the CMIP6 models across four forcing scenarios: SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. End-of-century Antarctic surface-air temperature changes across these scenarios (relative to 1995-2014) are 1.4, 2.6, 3.8 and 4.9 °C. The corresponding proportional precipitation rate changes are 8, 15, 23 and 30 %. Results will then be shown highlighting that across these scenarios projected changes over Antarctica and the Southern Ocean exhibit significant departures from a simple proportional link to global forcing. This is particularly apparent in the aggressive mitigation scenario (SSP1-2.6) which, compared to higher-forcing scenarios, exhibits stronger global-relative 21st century warming over coastal Antarctic and the Southern Ocean. Internal ocean dynamics and projected recovery of Southern Hemisphere (SH) stratospheric ozone both appear to play a role. These results highlight the importance of accurate representation of key regional processes, some of which are still not widely incorporated in contemporary climate models.

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Improvements in Circumpolar Southern Hemisphere Extratropical Atmospheric Circulation in CMIP6 Compared to CMIP5

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One of the major globally relevant systematic biases in previous generations of climate models has been an equatorward bias in the latitude of the Southern Hemisphere (SH) mid-latitude tropospheric eddy driven westerly jet. The far reaching implications of this for Southern Ocean heat and carbon uptake and Antarctic land and sea ice are key reasons why addressing this bias is a high priority. It is therefore of primary importance to evaluate the representation of the SH westerly jet in the latest generation of global climate and earth-system models that comprise the Coupled Model Intercomparison Project Phase 6 (CMIP6). In this paper we assess the representation of major indices of SH extratropical atmospheric circulation in CMIP6 by comparison against both observations and the previous generation of CMIP5 models. Indices assessed are the latitude and speed of the westerly jet, variability of the Southern Annular Mode (SAM) and representation of the Amundsen Sea Low (ASL). These are calculated from the historical forcing simulations of both CMIP5 and CMIP6 for time periods matching available observational and reanalysis datasets. From the 21 CMIP6 models currently available there is an overall reduction in the equatorward bias of the annual mean westerly jet from 1.9° in CMIP5 to 0.7° in CMIP6 and from a seasonal perspective the reduction is clearest in austral spring and summer. This is accompanied by a halving of the bias of SAM decorrelation timescales compared to CMIP5. However, no such overall improvements are evident for the ASL.

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Future climate response to Antarctic Ice Sheet melt produced by anthropogenic warming

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Observational evidence indicates that the Antarctic Ice Sheet (AIS) is losing mass at an accelerated rate while ice sheet models highlight the potential for a significant future ice collapse in the next few centuries. The impacts of increased freshwater runoff and ice discharge into the ocean from a retreating ice sheet are now only beginning to be explored, and remain poorly constrained. Here, we report on changes to the climate system over the next 250 years (present to 2250CE) projected by a fully coupled global climate model (CESM 1.2) run under future greenhouse gas emissions scenarios IPCC RCP4.5 and 8.5, with meltwater discharge provided by a dynamic-thermodynamic Antarctic Ice Sheet model. The multi-century length of these simulations includes the full collapse of the West Antarctic ice sheet in the ice sheet model in the RCP8.5 run at ~2125CE in. We find that accounting for Antarctica's meltwater contribution raises sub-surface ocean temperatures at the ice sheet margin by more than 1°C, with the potential to substantially increase the rate of ice melt beyond current projections. In contrast, the surface freshening leads to a dramatic expansion of sea ice that causes Southern Hemisphere surface air and ocean temperatures to be 2-10°C cooler than experiments without meltwater from the ice sheet model. This change reduces projected global mean anthropogenic warming by 2°C during peak ice sheet collapse in experiment RCP8.5. Our results demonstrate a clear need to account for meltwater input from ice sheets if we are to make confident climate predictions.

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Mean state and future trends of Antarctic snow accumulation dominated by atmospheric synoptic-scale events

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The Antarctic continent has gained mass at its surface over the last century through increased snowfall, with a strong spatial variability. However, the mechanisms behind the snow accumulation changes are poorly understood. This limits our ability to assess precisely future projections of the Antarctic climate. Here, by analysing the Antarctic atmospheric moisture budget using reanalysis data and climate models, we show that the year-to-year variations in snow accumulation are governed by different processes than the multi-decadal snow accumulation changes. Our results reveal that both the moisture transport by the mean circulation and by short-lived synoptic-scale events control the inter-annual variability of regional snow accumulation. Yet, when considering the entire continent at the multi-decadal scale, only the synoptic-scale events can explain the snow accumulation increase over 1985-2014 AD and for the end of the 21st century. Our analysis indicates that, in a warmer world, these atmospheric synoptic-scale events transport more humidity due to increasing temperatures, which leads to more precipitation on the Antarctic continent and can therefore mitigate sea-level rise. Many studies have underlined the dominant contribution of the Southern Annular Mode in explaining variations of snow accumulation at regional scales but we show it has a much lesser role at the continental scale and on longer timescales. The mechanisms ruling accumulation changes identified from inter-annual changes over the last few years cannot thus be simply extrapolated to predict future accumulation changes.

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Projected Slowdown of Antarctic Bottom Water Formation in Response to Amplified Meltwater Contributions

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The overturning of Antarctic Bottom Water (AABW) is a major regulator of the storage of heat, carbon, and nutrients in the ocean. AABW sinking is sensitive to changes in surface buoyancy, in particular due to freshening since salinity plays a greater role in determining density at near-freezing temperatures. Acceleration in Antarctic ice-shelf and land-ice melt could thus significantly impact the ventilation of the world's oceans, yet future projections do not usually include this effect in models. Here we use an ocean–sea ice model to investigate the potential long-term impact of Antarctic meltwater on AABW overturning. The freshwater forcing is derived from present-day estimates of meltwater input from drifting icebergs and basal melt, combined with RCP2.6, RCP4.5, and RCP8.5 scenarios of projected amplification of Antarctic meltwater. We find that the additional freshwater induces a substantial slowdown in the formation rate of AABW, reducing ventilation of the abyssal ocean. Under both the RCP4.5 and RCP8.5 meltwater scenarios, there is a near-complete shutdown of AABW formation within just 50 years, something that is not captured by climate model projections. The abyssal overturning at ~30S also weakens, with a 20-yr delay relative to the onset of AABW slowdown. After 200 years, up to 50% of the original volume of AABW has disappeared as a result of abyssal warming, induced by vertical mixing in the absence of AABW ventilation. This suggests that climate change could induce the disappearance of present-day abyssal water masses, with implications for the global distribution of heat, carbon, and nutrients.

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COSMO-CLM2 : the regional climate model used for investigating the decadal variability and predictability of the atmosphere-ocean-ice sheet system over Antarctica.

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The climate of the polar regions, changing over the last decades, may result from external forcing, but also from natural interactions between its components (atmosphere, marine and continental cryosphere, and ocean). Quantifying the contribution of each is critical to understand decadal variability in the polar regions. The PARAMOUR project aims at revealing the fundamental drivers of climate variability and assessing the predictability in the polar regions. Coupling between the atmosphere, ocean and ice sheet regional climate models will enable to study the interactions between the atmosphere, ocean, sea ice and ice shelves at scales between a few hundreds of meters and a few kilometers, and investigate how these interactions influence the variability and predictability of the system, both in the past and in the future.
We present here the model used to represent the Antarctic climate: COSMO-CLM2. COSMO-CLM is a non-hydrostatic regional climate model, coupled to the Community Land Model 4.5. First, this coupled model was adapted for Antarctic conditions by updating the snowpack, roughness length of snow and the atmospheric stability parameters. A 30 years hindcast (1987-2016) simulation was performed and evaluated against a compilation of observational records, indicating that the COSMO-CLM2 model is capable of adequately simulating the Antarctic climate. Further studies have been led using COSMO-CLM2 to better represent the cloud-aerosols interactions and their impact on the radiative balance over the Antarctic ice sheet, as well as to include include a snowdrift routine to model the darkening of the surface due to scouring by the wind.

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Evaluation of the representation of surface mass balance in atmospheric reanalyses

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Regional climate models and reanalyses are tools to mimic the atmospheric processes over the Antarctic ice sheet. However, the mechanisms affecting the surface mass balance over Antarctica are not yet fully understood, constrained/parametrised by both climate models and reanalyses, which leads to biases in the representation of the Antarctic climate. This is not trivial, since these models are used to estimate the contribution of the AIS to sea level rise.

Therefore, an adequate representation of snow accumulation over the continent by the driving reanalyses is crucial. In that context, we evaluate the performance of four reanalyses: ERA-5 and ERA-Interim, CFSR, and MERRA-2 applied over Antarctica. Model outputs of accumulation are compared against observational datasets of surface mass balance (satellite records, in-situ stake measurements and ice cores, and reconstructions).

All reanalyses are able to capture the high accumulation event signals related to atmospheric rivers visible in 2009 and 2011 in Dronning Maud Land, but ERA-5 and ERA-Interim show the smallest bias in accumulation. Reanalyses display a correct representation of the large-scale accumulation patterns over the continent, but an underestimation of the surface mass balance at the coastal sites and the Antarctic Peninsula exists for Era-Interim and ERA-5. For inland sites, a good representation is achieved, apart from some limited locations which show an overestimation of the accumulated snow amount. MERRA-2 accumulation is best resolved over the coast but displays a general tendency to overestimate surface mass balance and CFSR displays a general underestimation of accumulation compared to the snow accumulation dataset.

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Validation of reanalysis Southern Ocean atmosphere trends using sea ice data

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Reanalysis datasets are an essential tool for characterising the state, variability, and recent changes of the atmosphere over the data-sparse Southern Ocean. They are important not just for meteorological research, but also for understanding ocean and sea ice changes, and for interpreting ice core records. However, different reanalyses show markedly different trends over the last four decades, and in ocean regions with no long-term in situ records it is difficult to validate such trends.
In this research, we use a novel analysis based one the expected coherence between surface air temperature and sea ice trends, to compare long-term changes in 8 different reanalysis products. Our analysis shows a surprising spread between the reanalyses in their sea ice-atmosphere coupling, with surface air temperature trends ERA5 and NOAA 20CRv3 products having the most consistent relationship with observed sea ice trends

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Ice flow velocity on Pine Island Glacier with offset-tracking technique

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This study analyzes the variability of surface flow velocity at 100 km inland of Pine Island Glacier (PIG), West Antarctica, during the 2014–2019 period. To determine the ice flow velocity variability, an offset-tracking technique was applied in sequential pairs of SAR images from Sentinel-1A (data acquired from Novembers), and a Digital Elevation Model (DEM) of TanDEM-X data. We detect a progressive acceleration of ice flow were glacier speed increased by up to 9.6% during the period. Wide fractures that propagate parallel to ice flow direction are identified in crevasses mapping. This fracture patterns identified throughout the study area contributed to identify the direction of flow. The contemporary increase in ice velocity of PIG suggest a continual thinning and ocean-driven changes of the glacier. These results corroborate with previous studies in West Antarctica and can be an indicator of environmental changes that occur in the Amundsen Sea region.

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Recent Antarctic climate change and its possible causes

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Since the year 1957, the Antarctic surface temperature has shown a substantial warming in the Antarctic Peninsula (AP) and west Antarctica, but there is little temperature change in east Antarctica (EA) and even a slight cooling trend. Although this asymmetric feature is well recognised, its origin remains poorly understood. By analysing observation data and multi-model results, this east and west Antarctic climate asymmetry is amplified in austral winter, originated from the ocean temperature over the Amundsen–Bellingshausen seas and the Antarctic terrain. The warmer ocean temperature over the West Antarctic sector has positive feedback, with an anomalous upper-tropospheric anti-cyclonic circulation response centred over West Antarctica, in which the strength of the feedback is controlled by the Antarctic topographic layout and the annual cycle. The cooling in east Antarctica is associated with the increase in sea ice that is caused by both changes in sea ice dynamics and thermodynamics. Since 2000s, there is a cooling trend in the Antarctic peninsula, while warming trend in east Antarctica, that seems to be caused by weakening of polar vortex in stratosphere.

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Understanding observed trends and future projections of the Southern Ocean warming and sea level change

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The Southern Ocean is one of the key regions absorbing the excess heat stored in the climate system due to anthropogenic warming with important implications for global and regional sea level change. Historical datasets and climate model simulations show some common features of the Southern Ocean climate change including the rapid warming along the mid-latitude band and the meridional dipole structure of sea level changes with faster (slower) sea level rise at middle (high) latitudes. Firstly, we combine observations and climate model simulations to identify climate drivers of the observed changes. While the historical changes (e.g., since 1960) could be mainly attributed to the anthropogenic forcing, the much larger changes occurred over the recent Argo period (since 2006) are largely due to the internal climate variability that is partly connected to the tropical forcing. Secondly, we explore the impacts of model mean state biases on future projections. Most of the CMIP5 models show equatorward biases in their simulated Southern Ocean westerly winds, which have been improved in CMIP6. For those models with the westerly winds biased more equatorward, the boundary between the subtropical gyres and the ACC where the projected ocean warming peaks is also located further equatorward. Larger poleward shifts of the westerly winds and the subtropical gyres are also projected, accompanied by larger magnitudes of ocean warming and sea level changes. Thirdly, we estimate the time when the future sea level change signal will exceed the range of internal variability, i.e. Time of Emergence, in the Southern Ocean.

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Heat and carbon pathways between the atmosphere and Southern Ocean over the 21st century under the RCP8.5 scenario

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The global oceans are a major sink of anthropogenic CO_2 and heat. This oceanic uptake impacts the ocean through changes to its chemistry and temperature. This study explores when, where, and how the pathways for oceanic uptake of heat and carbon will diverge in the “Business-as-Usual” (RCP8.5) scenario of atmospheric CO_2 changes over the 21st century. To account for mesoscale processes we used the 0.1°-resolution Ocean Forecasting Australia Model.

Regionally, the southern hemisphere oceans are projected to account for about 40% (for heat) and 55% (for carbon) of the global ocean surface uptake, and more than half of the subsurface storage for both heat (~50%) and carbon (60%), over the 21st century. In terms of oceanic effects of heat and carbon south of 40°S, a decrease in the mean annual sea surface pH (from 8.05 to 7.72) and an increase in mean annual SST (from 6.1 to 7.7°C) are projected by 2100. The ocean south of 40°S will continue to be the major hotspot for both heat and carbon uptake throughout this century, whereas the largest changes in southern hemisphere heat and carbon storage occur in the subtropics (10 to 40°S). This work highlights both the importance of the Southern Ocean to atmospheric removal of carbon and heat and therefore climate change, and the regional differences in uptake and storage. Clearly understanding and quantifying these changes is essential for current and future research on the impacts of climate change on the marine environment.

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SO-CHIC: South Ocean Carbon and Heat Impact on Climate

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SO-CHIC (2019-2023) is a project funded by the EU's Horizon 2020 programme with 15 partners from 10 countries.

The Southern Ocean (SO) regulates global climate, controlling heat and carbon atmosphere-ocean exchanges. Rates of climate change on decadal timescales depend on processes taking place in the SO, of which little is known. Limitations come from a lack of observations and the SO's sensitivity to intermittent small-scale processes poorly captured in Earth system models. To reduce climate prediction uncertainties, SO-CHIC aims to understand and quantify SO heat and carbon budget variability by investigating key processes controlling atmosphere-ocean-sea ice exchanges with observational and modelling approaches. SO-CHIC will:

Initiate sustained monitoring of SO heat and carbon budgets, quantifying fluxes at the air-sea-ice interface and estimating interannual heat and carbon storage variability.

Improve understanding of the spatial distribution and variability of heat and carbon exchanges between the atmosphere and the deep ocean, focusing on the dynamics of the ocean mixed-layer and its relation to sea ice distribution, and assessing the causes of the Weddell Polynya in 2016 and 2017, over 40 years since its previous occurrence.

Improve understanding of bottom water formation and export in the Bottom Boundary Layer and propose new strategies to represent such key processes – major shortcomings of current models.

Identify critical SO climate system sensitivities that must be correctly represented in models to reduce uncertainties in future oceanic heat and carbon projections.

Enable free and open access to all data, maximising impact on IPCC reports, climate services, and climate-model groups.

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The commitment to global sea level rise over the next 500 years

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Within Australia alone, more than A$226 billion of coastal infrastructure is vulnerable to the anticipated rise in sea level by the end of the century. The IPCC Fifth Assessment Report concluded that the likely increase in global-mean sea level during the 21st century ranges from 26-55 centimetres (under the low-end RCP2.6 climate scenario) to 45-82 centimetres (under the high-end RCP8.5 climate scenario). However, subsequent modelling studies have demonstrated the potential for the Antarctic Ice Sheet to undergo irreversible collapse during the coming centuries. Sea level increases of up to 2.5 metres are therefore possible by the end of the 21st century.

Here, we combine climate modelling and ice sheet modelling to explore the evolution of the Antarctic Ice Sheet over the next 500 years under a range of climate scenarios. We run the models many times to account for gaps in our understanding of ice sheet dynamics, using our knowledge of past changes in the Antarctic Ice Sheet to identify the configurations that are plausible. This allows us to generate robust projections of the Antarctic contribution to global sea level from the present to the year 2500, complete with quantified confidence intervals.

We conclude that the sea level contribution during the 21st century will be modest, consistent with the IPCC Fifth Assessment Report, but that melting of the Antarctic Ice Sheet will accelerate thereafter. We also conclude that previous studies have underestimated the range of uncertainty in projections of future global sea level rise.

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Contrasting responses of marine and land-terminating glaciers to recent climate variations in King George Island, Antarctica

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In this study, we aim to analyze the marine-terminating glaciers in King George Island (KGI) (Antarctica) between 1956 and 2019. Glacial fluctuations are estimated using spaceborne remote sensing data (SPOT, Landsat, PlanetScope, Sentinel-1, Sentinel-2, WorldView-2, and TanDEM-X). The KGI witnessed continuous glacier retreat during 1979–2019, but the new land-terminating glaciers showed a deceleration in 2000-2019 in comparison to previous years (1988-2000). Seven marine-terminating glaciers changed to land-terminating condition since 1979. The accumulation area ratios (AARs) exhibiting negative mass balances. The winter air temperature was cooler during the 1970s with warming trends in the 1980s and early 2000s followed by a cooling trend until the present day. However, the annual time series has shows high interannual variability in air temperature during these periods. We show that the AAR, dimensions, length, frontal elevation, maximum elevation, slope, and changes in the terminus position influence the glacier response to climate change at different timescales. Furthermore, three geomorphic activity intensity zones and a complete paraglacial sequence are identified while contrasting the proglacial systems.

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Evaluating Antarctic precipitation in ERA5 and CMIP6 against CloudSat observations

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Surface total precipitation – the main positive term in the antarctic ice sheet mass balance – as well as temperature are projected to increase in the future according to global climate models. Sparsity of observations – due to the unpropitious environment for instrumentation – limits our confidence in numerical atmospheric models in the South pole region. Therefore, satellite-based observations are valued data that make it possible to evaluate recent models outputs : the CMIP6 (Coupled Model Intercomparison Project phase 6) ones have just been provided allowing an assessment of their progress regarding the previous phase with various setups. The reference for snowfall is the first snowfall climatology map for Antarctica – based on the CloudSat satellite Cloud Profiling Radar - produced (Palerme et al. 2014) at the surface - completed recently (Lemonnier et al. 2019) on its vertical dimension. Results from the reanalyses ERA5 of the ECMWF are evaluated because they are often used as a reference in regions where there is a lack of observations.

At continental and regional scales, ERA5 and CMIP models median are biased high. However, there are less models outputs with large overestimations in CMIP6, and the seasonal cycle is well reproduced by the median of the CMIP models – but not by ERA5. From all the configurations evaluated, amip ones perform better than historical. Relative errors in areas of complex topography are higher in the higher resolution models that is unexpected. No significant improvement are shown from CMIP5 to CMIP6 despite near-surface temperature enhancement.

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Present and future of rainfall over Antarctica

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Rainfall events in Antarctica are not well referenced and currently not the subject of a major attention. This is because its proportion – both in terms of occurrence and quantity with regards to the solid phase of precipitation – and mainly its impact on the surface mass balance of the ice sheet is very low.
However, rainfall events can cause serious damages on the Antarctic fauna and they can play a major rôle in snowmelt events by preconditioning the snow surface.
Making use of statistics base on in-situ observations, we show that rainfall events can occur along a large part of the Antarctic edge, and they can sometimes even protrude further inland. Thanks to those data we could evidence an under-estimation of Antarctic rainfall occurrence in the ERA5 reanalyses. We further attempted to characterize Antarctic rainfall with remote-sensing methods but the limitation of the current products preclude any robust conclusion.
To better predict the effect of climate change on Antarctic rainfall, the recent releases of simulations from the CMIP6 (Coupled Model Intercomparison Project) models are then used to study the evolution of rainfall under different climate scenarios. The overall increase in temperature and precipitation on the ice cap is in agreement with previous study using CMIP5 models but we further show a significant increase in the amount and occurrence of liquid precipitation over a large part of the ice sheet. In addition, we provide a detailed analysis on the regional pattern and on the seasonal cycle of the liquid precipitation.

SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 4

POLAR METEOROLOGY: SHORT TERM CLIMATE VARIABILITY

David Bromwich
Steve Colwell, Adriana Gulisano

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

1507

Identification of a possible channel in the trajectory of air masses between Subtropical South America and Antarctica in 2016 and 2017

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This study explores interactions between the Antarctic and South American (SA) air masses and a snow pit located in Criosfera 1 (C1 - 84°S 79° 29' 39"O), between 2016 and 2017. This interaction was responsible for precipitation events in southern Brazil (SB). The period studied stands between the three global warmest years, as well as being the third and fourth in SA, respectively. The rain was collected in the city of Porto Alegre with a Palmex RS1 sampler; snow samples were collected a 2.5 meters depth snow pit in December 2017 (C1). The oxygen isotope ratios were determined by Cavity Ring-Down Spectroscopy (Picarro system). were analyzed the geopotential height fields, wind vectors, temperature and precipitable water at 925, 850, 500 and 200 hPa (monthly and seasonal), using ERA5 Reanalysis data. The polar fronts associated with low and high level atmospheric circulation strengthened convection and the development of severe storms in the SB. Three sources of moisture are associated with this mechanism: Amazonian Forest, South Atlantic Ocean and Antarctica/Weddell. A contrast of temperature was observed with the circulation of air masses, channeled between La Plata Basin/SB/SA and the Antarctic Peninsula/Weddell, increasing the storms in the SB and the trench in C1 (by the isotopic signal). The δ18O values found in precipitation show high variability, from -2.93 ‰ to -9.80 ‰ and show the different sources of air masses and seasonal signal (summer/winter)in Porto Alegre; and seasonal signal of -30.93 ‰ (summer); and up to -45.80 ‰ (winter) on site C1.

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Observing System Experiments in the Antarctic with the Antarctic Mesoscale Prediction System (AMPS)

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The Year of Polar Prediction in the Southern Hemisphere (YOPP-SH) had a Special Observing Period (SOP) that ran from mid-November 2018 to mid-February 2019. The goal of YOPP-SH is to advance environmental prediction capabilities for the Antarctic and Southern Ocean region. Around 2200 additional radiosondes and an enhanced drifting buoy network in the Southern Ocean were deployed for this austral summer SOP. Here, the impact of the additional radiosondes on the forecast skill of the Antarctic Mesoscale Prediction System (AMPS) is examined with Observing System Experiments. Forecasts are run with and without the additional radiosonde profiles in the model initialization; satellite radiances were not assimilated for this initial evaluation. This study launched 72h experimental forecasts from ensemble mean analyses that initialized at 0000 and 1200 UTC each day for 52 days (December 28, 2018 – February 17, 2019). Results show that the additional radiosondes yield the greatest forecast improvement for deep cyclones near the Antarctic coast, specifically over Amundsen-Bellingshausen Seas and King Haakon VII Sea. Averaged for January 2019, surface pressure and upper level geopotential height are the variables that had the most improvement, followed by the 10m wind speed and 2m temperature over Antarctica. In the next project phase, a refined data assimilation approach will be adopted for the experimental run and satellite radiances will be assimilated. The experimental run will also be extended to span the entire SOP, and more case studies will delve into the causes of the wide range of forecast behavior exhibited.

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The influence of the oceanic mesoscale on the lower atmosphere

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The influence of the oceanic mesoscale on the lower atmosphere in the high latitudes regions, the Drake Passage, the Bellingshausen Sea and the western region of the Weddel Sea, was analyzed in this work through the regional numerical simulations using the Coupled Ocean Atmosphere Wave Sediment Transport (COAWST) Modeling System. The COAWST system components used were: the atmospheric model Weather Research and Forecasting (WRF), the ocean model Regional Ocean Modeling System (ROMS) and the Sea Ice Model. The simulation period was one month, November 2019, simultaneous to in situ measurements made by the AnTarctic Modeling Observation System (ATMOS) project. The field experiment was developed during Phase II of the Antarctic Operation XXXVIII (OP38). The in situ data, reanalysis data, and satellite images were used to verify the model's ability. In addition, the Locally Weighted Smoothing (LOESS) filter implemented within COAWST was used, to remove high frequency from sea surface temperature (SST) before it is passed to the atmospheric model. Thus, in this work, first we will present COAWST as a useful tool for studies of ocean-atmosphere-sea ice interaction in high latitude regions. Also, demonstrate how positive SST perturbations can lead to positive perturbations on the lower atmosphere momentum, sensible and latent heat fluxes perturbations. These positive perturbations influenced the development and stability of the marine atmospheric boundary layer (MABL), causing a more unstable and deeper MABL than the observed over the negative SST perturbations.

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Ocean wave climate on Bransfield Strait

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The Bransfield Strait, located between the South Shetland Islands and the north of the Antarctic Peninsula, is on the edge of the seasonal sea ice cover, and is a region of access to scientific research bases, being important the knowledge of the wave climate in this area to study the interaction of this physical phenomenon with sea ice and icebergs, as well as for navigation safety. To characterize preliminary the wave climate in the region, a global simulation with WW3 (25 km of spatial resolution) was carried out from 1998 to 2019, with two points selected for analysis of the main waves parameters, the significant wave height (Hs), peak period (Tp) and peak direction (Dp). One of these points refers to the buoy location (P1 – 58.16ºW, 62.19ºS) close to Almirantado Bay (King George Island). The other point is located in a central region of the Strait (P2 - 57.88ºW, 62.53ºS). In P1, the most intense wave systems (99th percentile) were from E-SE during summer and autumn, with some cases from S-SW during summer and E-NE during winter and spring. In P2, the most intense wave systems were from W-SW, with larger number of cases in June and September. A higher resolution simulation over the Strait region was done during the buoy record period, showing correlation of 0.81 and RMSE of 0.54. The WW3 model simulations followed the oscillations presented by the buoy, understimating Hs values, probably due to the choice of the atmospheric forcing.

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Autonomous Observations of the Atmospheric Boundary Layer Over Ice Sheets and Sea Ice

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Unmanned aerial systems (UAS) and automatic weather stations (AWS) have been used to study the atmospheric boundary layer in the polar regions. AWS observations from a 30 m tower on the Ross Ice Shelf, Antarctica have been made since 2011. Six field campaigns, using small UAS, have been conducted throughout the annual cycle and over ice sheet, sea ice and bare ground locations in the Antarctic from 2012 to 2017. The AWS and UAS data capture a wide range of boundary layer conditions including strongly stable, very shallow boundary layers, shallow wind-mixed boundary layers, and deep convective boundary layers. Analysis of this data offers insights into the processes that control the thermodynamic state of the lower atmosphere and how the atmosphere interacts with the underlying ice surface. Examples illustrating the range of boundary layer states will be presented. This presentation will conclude with a discussion of a new 30 m AWS that will be installed in West Antarctica as well as present initial results from UAS flights conducted over the central Arctic in late-winter as part of the MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate) expedition.

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Recent trends in the variability of Southern Hemisphere polar jet and its position based on CMIP6 models

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Poleward shift and strengthening of southern hemispheric jet streams are significant feature in southern hemisphere climate under future scenario of increased greenhouse gas concentrations. In this study, we utilised recently available models (27) from the World Climate Research Programme's phase 6 of the Coupled Model Intercomparison Project (CMIP6) to assess the diversity in the historical changes in the speed and meridional location of the polar front jet (PFJ). We used the ERA5 reanalysis dataset to evaluate the historical simulations of the polar jet stream by the CMIP6 models for the period 1979-2014. Based on the climatology of the PFJ from ERA-5, we selected the area of study as 40-70°S and from 400 hPa to 100 hPa to reduce altitude related bias. In order to assess the changes of the jet streams in terms of strength and the shift in the location, we performed a three dimensional analysis on CMIP6 model output.
Based on ERA5 data, PFJ shows significant annual strengthening at 1.374 ms-1decade-1 and poleward shift of 0.168 °/decade. Trend in the seasonal averages of wind speeds varies from 4.439 to 6.508 ms-1decade. Seasonal averages show a poleward shift from 0.976 to 1.512 °/decade.
The historical simulations of the CMIP6 models show a wide range of trends in meridional location and jet strength. 96% of the models show annual strengthening of PFJ while 89% of the models show annual shift towards the pole. Most significant strengthening is observed during the month of September, October and November

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Record warming at the South Pole during the past three decades

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Over the last three decades the South Pole has experienced a record-high statistically significant warming of 0.61 ± 0.34°C per decade, more than three times larger than the global average. Using an ensemble of climate model experiments, we find this recent warming lies within the upper bounds of the simulated range of natural variability. The warming resulted from a strong cyclonic anomaly in the Weddell Sea caused by increasing sea surface temperatures in the western tropical Pacific, which, coupled with a positive polarity of the Southern Annular Mode, advected warm, moist air from the South Atlantic into the Antarctic interior. These results underscore the intimate linkage of interior Antarctic climate to tropical variability. Further, this study shows that atmospheric internal variability can induce extreme regional climate change over the Antarctic interior, which has masked an anthropogenic warming signal there during the 21st century.

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Development of an Antarctic Regional Climate Centre (RCC) network

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World Meteorological Organisation (WMO) RCCs are centres of excellence that operationally generate regional climate products including climate monitoring and prediction in support of regional and national climate activities and thereby strengthen the capacity of WMO Members in a given region to deliver better climate services to national users. While all WMO RCCs are required to fulfil certain mandatory functions, the RCC concept includes flexibility to accommodate specific regional needs, capabilities and limitations. The concept also provides options to implement a single multi-functional entity or a distributed-function RCC-Network collaboratively implemented by a number of interested hosts.

The Arctic RCC network https://arctic-rcc.org/ is currently in a demonstration phase and an Antarctic RCC is being proposed based on the lessons learned from setting up the Arctic RCC network. A scoping workshop was held in Bologna in October 2019 and the outcomes of this workshop and the next stages for the development of the Antarctic RCC network will be presented.

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Difference in the annual snow accumulation rate between the Antarctic Peninsula and West Antarctica in the period 1981–2007

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We have investigated the variability of the net snow accumulation rate from 1981 to 2007 using two shallow ice cores, one from the Antarctic Peninsula (PA) [Detroit Plateau - 64°05'07"S, 59°38'42" W; 1,937 m a.s.l.] and other from the West Antarctica [Mount Johns - 79°55'S, 94°23'W; 2,100 m a.s.l.]. On the Detroit Plateau, only ~40 km from the west coast of the PA, the annual net snow accumulation rate was 2.44 m in water equivalent (w.eq.) showing a trend of +0.036 m a-1 in the period. On Mount Johns, a site within the West Antarctic ice sheet and about 600 km from the coast, the annual net snow accumulation rate was 0.23 m in w.eq. and without a statistically significant trend. The Amundsen Sea Low (ASL) is the main driver of the variability of snow precipitation between the PA and the West Antarctic ice sheet. The positive trend of the Southern Annular Mode (SAM) in recent decades and strengthened ASL, increased cyclonic activity and snowfall in the PA region. However, the spread of the El Niño-Southern Oscillation (ENSO) signal in the Southern Ocean, and the greater distance from the coast, contributed to the snow precipitation remaining stable in the Mount Johns during the period.

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Climate from the McMurdo Dry Valleys, Antarctica, 1986 – 2017: surface air temperature trends and examining seasonality

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The weather of the McMurdo Dry Valleys, Antarctica, has been continuously monitored since 1985 with currently 14 operational meteorological stations distributed throughout the valleys. At present, data from the Lake Hoare station represent the longest continuous (a short gap in 2012) record in the dry valleys and arguably on the Continent. A comprehensive examination of trends in the dry valley record was published in 2002. We present here an update of the record, adding on another 18 years and extending the climatic record to a period of 30 years in total. The mean annual air temperature and solar radiation in the McMurdo Dry Valleys varied between -14.7°C and -29.6°C and between 72.1 W m-2 and 122.4 W m-2, respectively. Air temperatures decreased from 1986 to 2006 at 0.7°C per decade at Lake Hoare, a trend that was previously reported only until 2001. No apparent trend was detected after 2006.
Based on the shift in atmospheric stability and associated up-valley warming from the coast and concurrent wind direction change, we propose to redefine summer season in the McMurdo Dry Valleys between November and February. The newly-defined seasons are based on physical observations and also align better with ecosystem ephemerality (productivity) in the region. Based on the physical process of up-valley warming (i.e., atmospheric stability) driven by the solar radiation, our redefined seasonality is universal and applicable to other ice-free regions in Antarctica.

1451

Sensitivity of the Ze-S relationship parameters to ice particle microphysics using radar and in-situ observations at the coast of Adélie Land, East Antarctica.

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Solid precipitation is the main input in the surface mass balance of the Antarctic ice sheets. Its quantification is complex due to the lack of data, difficult access on the field and the unsuitability of traditional gauges under harsh weather conditions. Ground-based remote sensing has proven useful for studying Antarctic precipitation, especially using precipitation radars (e.i. Gorodetskaya et al., 2015, Genthon et al., 2018). A power law between the radar reflectivity factor (Ze) and the solid precipitation rate (S) has been used to quantify snowfall. Currently, there are only two Ze-S relationships in Antarctica, parameterized using in-situ observations at the Dumont d'Urville station (DDU) on the coast of Adélie Land (Grazioli et al., 2017) and at the Princess Elisabeth station (PE) in the escarpment region of Dronning Maud Land (Souverijns et al., 2017) and averaged over a range of local snowfalls with different properties. The relationship parameters are highly dependent on the hydrometeor characteristics, which is particularly important when studying solid precipitation, due to the high variability of ice particle microphysical properties (e.g. shape, size, density). We use a unique dataset of two vertically-pointing micro-rain-radar observations with different vertical resolutions (15 and 100 m), in-situ snowfall rate measurements and a multi-angle snowflake camera to derive particle microphysics at DDU, provided by the APRES3-project. The analysis of the temporal variability of the Ze-S relationship parameters will be presented as well as the dependency on ice particle characteristics. This investigation is valuable to improve the interpretation radar-based measurements of snowfall in Antarctica.

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The CO_2 fluxes exchange between ocean and atmosphere at Austral Ocean

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The studies that increase knowledge of the ocean-atmosphere processes are important for weather forecast improvements and for the studies of global carbon fluxes budget. The Austral Ocean plays a major role in the global weather and climate, besides this area represents a significant global carbon sink area. The objective of this work is to investigate the behavior of turbulent CO_2 fluxes at high latitude under different atmospheric and oceanic conditions, during the trajectories of research vessels to the Austral Ocean. Meteorological data were collected by sensors installed in a micrometeorological tower (collected at high and low frequencies) at the front bow of a research polar ship called "Almirante Maximiano''. The sampling period was from November 07th to 21th, 2018 during the Antarctic Operation 37. The CO_2 flux in the ocean and atmosphere interface was calculated by the Eddy Covariance (EC) method. The wind data measurements over the oceans need corrections prior to the estimation of fluxes, due to ship movement. Statistical analyzes show a negative correlation between salinity and sea surface temperature with CO_2 fluxes. So, the warm and salty waters in part of Drake Passage behaved more as CO_2 Source. The cold and less salty waters of the Bransfield Strait behaved more as CO_2 sink. However, the atmosphere stability conditions impact de CO_2 fluxes as well, for the more stable (unstable) atmosphere the fluxes are directed to the ocean (atmosphere). Although the atmosphere stability conditions impacts on CO_2 fluxes, the sea surface temperature effects are more significant.

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A large information network for all scientific communities.

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A few decades ago the result of the research of different scientific communities announced the news of climate change and global warming, it is definitely taken by nations as a simple speculation and the image projected by the scientific community that predicted abnormal climates and in constant change is only aligned as a remote possibility, today this news is a reality; Temperatures in Antarctica that exceed 18.3 ºC have already been reported, we have lost 20% of ice on one of the islands in just 9 days, which leads to sea level rising much more, we also see how wildlife The wild in the region has been affected by climate change, and for many people it is usual to see snow every year in the Sahara, and these facts become normal or "natural" facts.
For these reasons, the scientific community must have more support from governments and start making global alliances that allow them to explore and share their knowledge with all regions, so that research can be applied together.
Currently, agreements with Argentina are being developed in Colombia and in a joint exercise monitoring stations have already been installed that allow access to different atmospheric measurements in real time, however these measurements should not only be shared between the countries of the agreement, but that they should be free consultation data, aiming in this way to create an international monitoring network with which we can take the necessary measures in the race against global warming and climate change.

1423

Representation of Antarctic atmospheric boundary layer properties in the NASA GEOS model framework

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Representation of Antarctic atmospheric boundary layer properties in the NASA Goddard Earth Observing System (GEOS) model framework

Recent high-resolution dropsonde observations from the 2010 Concordiasi field campaign in austral spring season show that surface-based inversions (SBIs) over Antarctica are frequently eroded, with well-mixed boundary layers occurring 33% and 18% of the time in West and East Antarctica, respectively. In this study, using the dropsonde observations, we evaluate the performance of the Modern-Era Retrospective analysis for Research and Applications, version 2 (MERRA-2) in representing the Antarctic boundary layer thermodynamic structure. Results show that MERRA-2 has a good overall representation of the Antarctic surface stability and correctly predicts 82% of the SBIs. However, an underprediction of less stable boundary layer occurrence, especially over the elevated East Antarctic plateau, is favored during conditions of increased lower tropospheric stability associated with model dynamics, indicating difficulty in parameterizing turbulence in very stable boundary layers. In addition, a lower tropospheric cool bias (first model level and above) is observed in the MERRA-2 reanalysis, especially over West Antarctica, which amplifies in the boundary layer during mixed conditions. The near-surface cold bias is most pronounced when the model fails to predict mixed layers over West Antarctica and is expected to negatively impact the representation of surface energy budget and melt processes. Results suggest that advances in modeling and data assimilation as well as improvements in parameterizing turbulence in very stable boundary layers may rectify the biases.

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Precipitation and atmospheric rivers from sub-Antarctic Chile to Antarctic Peninsula: transition between rain and snowfall

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Atmospheric rivers (ARs) impact Antarctic surface mass balance through transport of anomalous heat and moisture from subtropical regions. ARs reaching the Antarctic coast have a prominent impact on moisture and wind profiles, representing an extreme state of the troposphere (Gorodetskaya et al., 2020). Antarctic ARs have been linked to intense snowfall events (Gorodetskaya et al., 2014), a temperature record at the Antarctic Peninsula (Bozkurt et al., 2018) and major surface melt events in West Antarctica (Wille et al 2019). On the Antarctic Peninsula, the surface mass balance can be especially sensitive to AR events during summer, when surface temperatures vary around zero and frequent transitions occur between snow and rainfall. We use radiosonde, cloud and precipitation measurements, along with reanalysis products, to investigate the spatial and vertical structure of the ARs and impact on precipitation at the Antarctic Peninsula. The data from two Year of Polar Prediction endorsed projects are used - the Characterization of the Antarctic Atmosphere and Low Clouds (CAALC) project at King George Island and the Dynamics, Aerosol, Cloud, And Precipitation Observations in the Pristine Environment of the Southern OCEAN (DACAPO-PESO) project in Punta Arenas. We present case studies characterizing the temporal evolution of ARs, focusing on thermodynamic and dynamic conditions, and cloud microphysical properties, accompanying the transition between snowfall and rain. We also show the added value of increased frequency in radiosonde observations in improving the forecast of weather conditions during ARs, particularly precipitation, which have important consequences for air, ship and station operations in Antarctica.

A new blowing snow scheme to represent snow transport at the surface of the Antarctic Ice Sheet

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Current simulations of the Antarctic ice sheet surface mass balance are still uncertain since both precipitation and blowing snow processes are poorly constrained and likely lead to inconsistencies betweeen modelled and measured snow accumulation values. Here, we apply the PIEKTUK-B blowing snow transport routine, developed for the Canadian prairies by Déry and Yau (2001), over coastal areas in East Antarctica. This routine was tested with two sets of simulations: an offline simulation in order to evaluate PIEKTUK-B as implemented in the land part of CESM (CLM4.5), and simulations with the coupled COSMO-CLM2 model in which the horizontal transport of snow is taken into account as well as changes to the snow surface properties.

Results indicate that (i) both off and online simulations display similar blowing snow occurrence at three coastal locations , and (ii) the routine is able to reproduce the observed temporal variability in snowdrift fluxes in Adelie Lan. The prescribed relation linking wind speed and aeolian snow transport is similar to that of the observations, and in general the modelled transport discrepancies are a result of the misrepresentaton of wind speeds by the COSMO-CLM2 model, although a tendency to overestimate the observed transport rates at highest wind speeds is depicted.

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Wintertime wind-induced surface temperature anomalies in the Antarctic: A climatology based on MODIS and regional climate model data

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It is well-known that katabatic winds can be detected as warm signatures in the surface temperature over the slopes of the Antarctic ice sheets. For appropriate synoptic forcing and/or topographic channeling, katabatic surges occur, which result in warm signatures also over adjacent ice shelves. Moderate Resolution Imaging Spectroradiometer (MODIS) ice surface temperature (IST) data are used to detect warm signatures over the Antarctic for the winter periods 2002–2017. In addition, high-resolution (5 km) regional climate model data is used for the years of 2002 to 2016. We present a climatology of wind-induced IST anomalies for the Ross Ice Shelf and the eastern Weddell Sea. The IST anomaly distributions show maxima around 10–15K for the slopes, but values of more than 25K are also found. Katabatic surges represent a strong climatological signal with a mean warm anomaly of more than 5 K on more than 120 days per winter for the Byrd Glacier and the Nimrod Glacier on the Ross Ice Shelf. The mean anomaly for the Brunt Ice Shelf is weaker, and exceeds 5K on about 70 days per winter. Model simulations of the 2m-temperature, IST and 10m-wind are compared to the MODIS IST and automatic weather stations. Overall, show a very good agreement of the model data with observations is found. The model data show that the near-surface stability is a better measure for the response to the wind than the IST itself.

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High-resolution regional climate model simulations using CCLM for the Weddell Sea region of the Antarctic: Verification and near-surface climate

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The non-hydrostatic regional climate model CCLM was used for a long-term hindcast run (2002-2016) for the Weddell Sea region with resolutions of 15 and 5 km. CCLM was nested in ERA-Interim data and used in forecast mode. Two different turbulence parametrizations are used for the stable boundary layer. The performance of the model was evaluated in terms of temperature and wind using data from Antarctic stations, AWS over land and sea ice, operational forecast model and reanalyses data, and lidar wind profiles. For the latter comparisons, CCLM was used with 1km resolution. Overall, CCLM shows a good representation of temperature and wind for the Weddell Sea region. An extended period of 2002-2019 was used to investigate the near-surface climate in the Weddell Sea region, including the surface energy balance (particularly of coastal polynyas), katabatic winds, barrier winds at the Antarctic Peninsula (AP) and foehn winds at the AP.

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Large-scale feature of surface-based inversion layer over the traverse route from Syowa to the Antarctic interior in cold season

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Suface-based temperature inversion layer on the Antarctic ice sheet is a typical feature. Phillpot and Zillman [1970] estimated the distribution of the inversion intensity on the ice sheet as an average field from June to August based on the limited observation data. Since then, there have been few new collective observations that can update their figure, so their result is still cited as observation that represent the characteristics of the inversion layer in winter. This situation will continue for some time, but continuing to collect observational data that can be compared to their result is necessary to update the knowledge. On the other hand, the accuracy of numerical models has improved remarkably, Antarctic Meso-scale Prediction System (AMPS) using the Weather Research and Forecasting Model (WRF) has been carried out, and it has also been used for meteorological mechanism analysis and climate analysis. For such numerical models, validation regarding the reproducibility of the inversion layer on the Antarctic ice sheet is one of the points of interest.
In spring season, we carried out radiosonde observation during a traverse from Relay Point to Syowa Station in 2018 and from MD78 to Syowa in 2019. In this presentation, we describe the characteristics of the cross-sectional structure of the inversion layer along the traverse route, and discuss the new facts with some comparable results derived from a numerical model.

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Early indications of anomalous behavior in the 2019 spring ozone hole over Antarctica

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The quasi-stationary planetary wave (QSW) activity in the Antarctic winter stratosphere provides insights into the likely behavior of the ozone hole in the following spring months. Observation of anomalously large amplitude of the winter stratospheric temperature QSW serves as an indicator that strong disturbances to the polar vortex are likely to occur. These disturbances may lead to large reductions in both the area of the Antarctic ozone hole area and the overall amount of stratospheric ozone that is depleted. In the sudden stratospheric warming preconditions in 2019, the maximum QSW amplitude over Antarctica in August was approximately 12 K, which was only 2 K less than conditions prior to the unprecedented historical major Antarctic sudden stratospheric warming in 2002. Under these conditions, the Antarctic sudden stratospheric warming in 2019 had the potential to become an unusual event, which has been confirmed by the satellite ozone observations in September-October. The additional factors disturbing the Antarctic stratosphere in 2019 was anomalously warm sea surface temperatures in the central tropical Pacific Ocean and western Indian Ocean, and the descending easterly phase of the Quasi-Biennial Oscillation (QBO). The combination of these factors – the large amplitude of the QSW, the warm tropical sea surface temperatures and transitioning phase of the QBO – created the potential to cause the early disruption of the ozone hole and reduce the overall level of ozone depletion in 2019. This event probably brought important regional anomalies in weather conditions in the Southern Hemisphere.

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Where are all the Foehn impacted coastal regions of Antarctica?

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Intense warming events that are driven by intra-seasonal mesoscale weather variability cause seasonal streams to flood in the Dry Valleys and ice shelf melt in the Antarctic Peninsula. The Antarctic coastline topography acts to ground warm Foehn induced air masses impacting the near surface air temperatures. Due to Antarctica's complex topographic coastline and difficulty to numerically resolve or observe mesoscale weather circulation patterns at the continental scale, we hypothesize that Foehn induced warming is impacting most of the Antarctic rugged coastline and is gone undetected so far.
We have developed and validated an Antarctic wide near-surface AIR temperature dataset (AntAIR) at a daily and 1km resolution, which was based on statistical learning from satellite and in-situ observations suitable for mesoscale climatological analyses. AntAIR was used successfully to detect some of the Dry Valley Foehn cases that were independently verified with regional climate model outputs. Results show valley-wide warming patterns associated with Foehn that are distinct from patterns associated with surface radiative cooling in winter or solar warming in summer. We are also developing sub-kilometre land surface temperature datasets that take advantage of MODIS's daily resolutions and LandSat's high spatial resolutions, which will become useful for localized warming impacts on the terrestrial landscape. With the scarcity of Antarctic weather stations and the costs involved in developing numerical simulations at mesoscale resolutions, we propose that both AntAIR and newly developed automatic Foehn detection algorithms can be used to discover new areas impacted by extreme warming.

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Current state of snow cover in the area of Ukrainian Antarctic research base "Academician Vernadsky"

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The paper analyzes the results of comprehensive observations of the snow cover in the area of the Ukrainian Antarctic research base "Academician Vernadsky" for 1986-2019.
It has been established that the formation of a snow mass of 2-3 m high in the region occurs under relatively warm conditions (average January temperature of 0.7 °C, the sum of the temperatures of the winter months is -23.7 °C) and during long (6-7 months) winter. Because of it, snow falls wet, its temperature is close to 0 °C, the dynamic factor increases its density to 0.5 g/cm3 and higher.
The analysis showed a shift of the snow cover existence period in the study area to a later date, while its duration remains stable. The seasonal component (annual cycle) with a period of 366.04 days (which explains the shift) describes 58% of the total variability, and the long-period (period of 11 years) - 17.6%.
The increase in snow depth by the monthly section turned out to be a very informative and promising characteristic.
The delving of snow cover revealed the following features: during the snow accumulation season, the 6-7 permanent layers are usually formed during the season, although in some unstable winters their number may be greater. These layers are formed during specific time intervals, close in different years, under the influence of certain synoptic formations; the snowmelt period is characterized by 3-4 stable periods; an avalanche-hazardous layer of insignificant vertical thickness is formed during the period of maximum snow growth (July-August).

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Recent weakening of southern stratospheric polar vortex and its impact on the surface climate over Antarctica

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Variability of southern stratospheric polar vortex (SSPV) and its downward coupling with the troposphere are known to play a crucial role in driving climate variability over the Antarctica. In this study, the SSPV weakening events and their impact on the surface over the Antarctica are examined using in situ observation and reanalysis data. Combining rules in the several previous studies, we devised a new detection method for the weak SSPV event. Based on the new criteria, the occurrence frequency of weak SSPV events has exhibited a systematic increasing trend since the 2000s. However, the weakened anomalies of individual SSPV event were not particularly different between the earlier (1979-1999) and later periods (2000-2017). The recent increase in the occurrence of weak SSPV events is largely controlled by tropospheric mechanisms, the poleward heat flux carried by southern hemisphere planetary waves and related vertical wave propagation. We show that the SSPV weakening event induces statistically significant cooling over the Antarctic Peninsula (AP) region and warming over the rest of Antarctica. Typically, large negative values smaller than -0.6 ºC and positive values larger than + 0.8 ºC of surface air temperature anomalies are observed over the east coast of the tip of AP and the King Edward VII Land, respectively. The influence of weak SSPV on surface lasts for several months with higher height anomalies off west Antarctica, providing favorable conditions for the atmosphere to transport cold air from the interior of Antarctica to the AP via the Weddell Sea.

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Shallow convection and precipitation over the Southern Ocean: A case study during the CAPRICORN field campaign

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Persistent biases in the energy budget over the Southern Ocean (SO) within climate simulations and reanalysis products have been linked to the poor representation of clouds over the region, particularly in regions of shallow, post-frontal convection. In response to these challenges, the CAPRICORN (Clouds, Aerosols, Precipitation, Radiation, and atmospherIc Composition Over the southeRn oceaN) field campaign was carried out to characterize the cloud, aerosol, precipitation and boundary layer properties over the SO. The Australian R/V Investigator undertook a 35-day cruise from March to April in 2016 making observations from Hobart (43°S) to the polar front (53°S). One case is examined in this study with a focus on shallow convective clouds that were commonly observed during the cruise. Shipborne measurements, Himawari-8 products are integrated to investigate the dynamical and microphysical characteristics of the targeted marine boundary layer cloud fields. This case (26-28 March) focusses on a sustained period of open mesoscale cellular convection in a post-frontal environment. The observed cloud field resided primarily below 2.5 km and in the sub-freezing temperature range (0 to -8°C), where mixed-phase cloud tops were suggested by both the shipborne and Himawari-8 observations. Relatively heavy precipitation was observed to be generated from these clouds. High-resolution simulations with a convection-permitting configuration of the Weather Research and Forecasting (WRF) model are performed with relatively good representation of some surface meteorology. However, simulations have difficulties in producing both the low-level cloud field, mixed-phase cloud tops, boundary-layer decoupling and surface precipitation.

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West Antarctic Surface Melt: Energy Budget, Meteorological Drivers and Large-Scale Climate Forcing

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Surface melt over West Antarctica is increasingly recognized as a contributor to ice mass loss, through hydrofracturing of ice shelves that buttress ice sheets. The US Department of Energy Atmospheric Radiation Measurement (ARM) Program West Antarctic Radiation Experiment (AWARE) provided insight into lower atmosphere perturbations and the influence of cloud microphysics on the surface energy balance. Here we generalize AWARE objectives to identify meteorological drivers of surface melt throughout West Antarctica. We diagnose these drivers of surface melt by comparing satellite-observed melt patterns to anomalies of near-surface air temperature, winds, and satellite-derived cloud cover, radiative fluxes and sea ice concentrations spanning the austral summers 1979-2017. Summertime melt-inducing warming is favored by Amundsen Sea (AS) blocking activity and a negative phase of the Southern Annular Mode, both of which correlate with ENSO conditions in the tropical Pacific Ocean. Extensive melt events in the Ross-Amundsen sector of the West Antarctic Ice Sheet (WAIS) are linked to intense and persistent AS blocking anticyclones that force intrusions of marine are over the ice sheet. Surface melting is driven primarily by enhanced downwelling longwave radiation and turbulent mixing of sensible heat to the surface by föhn winds. Since the late 1990s, concurrent with ocean-driven WAIS mass loss, summer surface melt has increased from the AS Embayment to the eastern Ross Ice Shelf. Increasing anticyclonic advection of marine air over the WAIS, and enhanced air-sea fluxes associated with declining sea ice concentration in the coastal Ross-Amundsen Seas, together provide a possible mechanism for this trend.

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Atmospheric Warming-Induced Surface Melt in West Antarctica: Recent Field Observations and Climate Change Context

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Recent remote sensing and climate modeling studies show that summer surface melt over West Antarctica is more frequent and widespread than previously realized, and that surface meltwater can substantially weaken ice shelves and ice cliffs through hydrofracturing. When evaluating the role of atmospheric warming in West Antarctic Ice Sheet (WAIS) loss, the key considerations are not necessarily the total resulting meltwater volume and geographic extent as over Greenland, because most WAIS melt events last only a few days. Instead, one should focus on surface melt specifically over vulnerable ice shelves and ice cliffs that can weaken their structure even if short-lived. Surface melt generally results from changing radiative and turbulent flux components of the surface energy balance when surface and lower atmosphere temperatures are near the freezing point. In Antarctica the meteorological drivers of these changes vary, and we review three based on observations. During the joint US NSF-DOE Atmospheric Radiation Measurement (ARM) Program West Antarctic Radiation Experiment (AWARE), radiation and turbulent flux instrumentation at WAIS Divide diagnosed the role of cloud longwave surface heating during the extensive January 2016 melt event. In a recent field program at Siple Dome during December 2019-January 2020, similar instruments provided new data on the role of optically thin clouds that induce an all-wave surface radiative flux enhancement similar to what has been discovered over Greenland. Analysis of automatic weather station (AWS) data near the Transantarctic Mountains enables us to quantify the role of foehn winds in localized surface melt events.

1540

An Examination of the ERA5 Reanalysis Dataset over the Ross Ice Shelf using Observations from a large scale SNOW WEB deploymnet

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This study compares meteorological output from the ERA5 reanalysis product with a large scale deployment of the SNOW WEB observational network over the Ross Ice Shelf. Deployments of 14 SNOWWEB stations in the 2017/2018 Antarctic field season through to the present day and a second deployment since the 2018/2019 of a further 12 SNOWWEB stations are used to compare with ERA5 winds, temperatures and pressures. We also use our observational network to identify potential gaps in the existing observational network. The earlier deployment occurred along a 240 km transect along the South Pole Traverse route and the second was from Siple Dome to a region on the Ross Ice Shelf close to the Kamb icestream. We also use a Self-Organizing Map analysis to compare the ERA5 model output with data from our observational network under a varying range of synoptic conditions. We also examine the quality of the reanalyses to represent the relationships between these synoptic conditions and snowfall events using ancillary datasets. This analysis allows a quantification of the impact of synoptic states and their representation on snowfall. We also focus on whether extreme events observed by the SNOWWEB stations related to periods of significant snow accumulation are represented correctly in the ERA5 reanalysis.

1454

CO2 flows in the Bransfield Strait during the austral summer 2018

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An estimated that 30% of the CO2 present in the atmosphere has been absorbed by the oceans, however, this sink characteristic has been affected due to the increase of this gas in the atmosphere. To understand these processes the Bransfield Strait and the surroundings of Elephant Island have been chosen, which is affected by the Bellinghausen Sea (TBW), the Weddell Sea (TWW) and the Scottish Sea.
Data on sea surface temperature, salinity, dissolved oxygen, chlorophyll-a, wind speed and partial CO2 pressure (pCO2) have been used and then treated by a GIS to space them along the Strait. The results indicate that there are two well-defined bodies of water, TBW characterized by a temperature between 1 to 2 °C and salinities 33.8 to 34.2; TWW with -0.7 to 1 °C and with salinities 34.2 to 34.5. The dissolved oxygen shows a heterogeneous surface distribution and chlorophyll-a values less than 1 µg/L, the wind speed reaches values of 6 m/s in the Strait and values of 10 m/s in faraway areas. The difference between the ocean atmospheric pCO2 and ocean pCO2 were positive, this indicates that ocean CO2 is being transferred into the atmosphere (~ 5 at 20 mmol.m-2.day-1). A relationship was also found between CO2 absorption and sea ice coverage, with the greatest absorption occurring when sea ice is scarcer or seasonal, while it decreases when ice coverage increases.

829

Antarctic Regional Warming Events in Winter Observed by the University of Wisconsin-Madison Automatic Weather Station Network: An Analysis of Extreme Temperature Increases on the Ross Ice Shelf

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Previous studies of Antarctic climate have highlighted relatively uniform, cold conditions throughout the austral winter. Other studies, however, have shown warming deviations occurring on monthly timescales during the winter. One cause for these increases in temperature may be brief but rapid increases in surface temperature. Observations from the University of Wisconsin-Madison (UW) Automatic Weather Station (AWS) network have shown dramatic and rapid increases in temperature in austral winter. An investigation of these events was conducted for all UW AWS in the years 2002 through 2018. These warming events in winter (WEW) are defined as increases in temperature observed at a UW AWS of 30 degrees C or greater in 5 or fewer days, with a decrease in temperature during that period of no more than 10 degrees C. A regional warming event in winter (RWEW) was subsequently defined as an event that included one or more WEW occurring in the same predefined region at about the same time. The Ross Ice Shelf (RIS) observed the most WEW and RWEW in this study. An analysis of 500 hectopascal (hPa) geopotential height anomalies during RWEW revealed that RWEW in the RIS had the largest variability in said height anomalies. Smaller-scale processes are hypothesized to lead to RWEW in this region, including turbulent mixing. Presented will be typical large-scale atmospheric flow regimes preceding RWEW on the RIS. A case study analysis will be presented of an RWEW that occurred on the RIS between 12 and 15 July 2007.

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On the 16-year periodicity in the Antarctic Peninsula temperature variability

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Surface temperature in the Antarctic Peninsula (AP) region increased rapidly since the middle of the last century and shows no warming since the 2010s. In addition, long-term climate changes across AP vary both seasonally and spatially. The distinctive role of the decadal periodicity in the change in winter temperature (June–August) in the northern and southern AP is analyzed. The Scientific Committee on Antarctic Research Reference Antarctic Data for Environmental Research (SCAR READER) was used. The time series 1952–2017 for the two AP weather stations Esperanza (northern AP) and Vernadsky (southern AP) were compared. If the Esperanza data show a stable 16-year periodicity, then the Vernadsky data show irregular decadal variability. This is clearly seen from the wavelet transforms, which also display opposite phases in the recent temperature change with warming at Esperanza and weak cooling at Vernadsky. The spatial heterogeneity in temperature variations along AP is usually attributed to the competing impacts of the El Niño–Southern Oscillation and Southern Annular Mode. We have revealed that the periodic temperature oscillation at Esperanza is associated with the latter mode combined with the zonal wave 3 pattern. In the related surface pressure anomalies, wave 3 ridge located east of southern South America is the cause of the regional anticyclonic anomaly. The corresponding westerly wind anomaly covers Esperanza in the northern AP but does not reach Vernadsky in the southern AP. This leads to a differentiated contribution of decadal variability to temperature changes along AP.

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Sudden Stratospheric Warming over Antarctica in 2019 and the hemispheric implications

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In late August to early September of 2019, the temperature in the mid- and low stratosphere over Antarctica rose by over 70 degrees Celsius. This event is later confirmed as a Sudden Stratospheric Warming over Antarctica (SSWA) for the second time only after the event in 2002. Along with the SSWA, the ozone depletion does not prevail as usual in the springtime. The zonal mean temperature (60-90S) and wind (60S) show that the event could be resulting from the planetary waves' propagation into the stratosphere and weakening the polar vortex. Whereas, another possible explanation is that the warming over Antarctica is simply mirroring the cooling over the Arctic in 2019, configured by the satellite anomalies in the low stratosphere. The SSWA event causes some hemisphere-scale disturbances. For example, the sea-ice extent and area in Antarctica reach their minimum level throughout the last 40 years; and unusual drought and bushfires spread in the east part of Australia.

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Seasonal variability of net sea–air CO_2 fluxes in the northern Antarctic Peninsula

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Several studies have been conducted in the Antarctica to investigate the net sea–air CO_2 fluxes (FCO_2). However, the Antarctic coastal regions are still poorly sampled and the majority of the studies are restricted to the austral summer. Here, we constructed a temporal series (2002-2017) of hydrographical and biogeochemical data in Gerlache Strait, a hotspot for climate change that is ecologically important in the northern Antarctic Peninsula. Thus, we show for the first time a detailed annual overview of the FCO_2 and primary drivers in the Gerlache Strait. In autumn and winter, episodic upwelling increases the remineralized carbon in the surface, leading the region to act as a moderate or strong CO_2 source to the atmosphere of up to 50 mmol/m²/day. During summer and late spring, photosynthesis decreases the CO_2 partial pressure, enhancing ocean CO_2 uptake higher than –50 mmol/m²/day. Therefore, the autumn/winter CO_2 outgassing is nearly balanced by an only 4–month period of intense ocean CO_2 ingassing during summer/spring. Hence, the estimated annual FCO_2 from 2002 to 2017 was 1 ± 17 mmol/m²/day. The main drivers of changes in the surface CO_2 system were total dissolved inorganic carbon and total alkalinity, revealing the dominant influence of both physical and biological processes. These findings demonstrate the importance of Antarctica coastal zones as carbon sinks and emphasize the need to better understand the sensitivity of the local/regional Southern Ocean carbon cycle to the impacts of climate change.

1066

Antarctic convection west of Maud Rise.

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Maud Rise, a seamount in the Weddell Sea, is a location where a polynya occasionally forms. The most dramatic of these events was the ~300,000km2 polynya that occurred over the 3-year period from 1974-1976. Another smaller polynya developed in 1994. In 2016, a polynya developed near Maud Rise in late July and persisted for approximately 3 weeks. In September 2017, the polynya returned and remained open through November. The presence of a polynya can lead to vigorous air-sea interaction resulting in a densification of the surface waters and a convective overturning of the water column that was indirectly observed after the 1976 polynya and directly observed during the 2017 event. There is still much that is unknown regarding how these polynyas form as well as the characterization of the atmospheric forcing that occurs within them and the oceanic response. Here we use a new high resolution atmospheric reanalysis to compare and contrast the meteorological conditions associated with the polynyas from the 1970s with those from the more recent openings. Included will be a characterization of the spatial and temporal variability in the air-sea interaction that occurred within these polynyas.

1404

An overview on the Southern Hemisphere storm tracks from the Brazilian earth system model' RCP8.5 Scenario

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The Brazilian Earth System Model (BESM) consists of a coupled climate model developed by the National Institute for Space Research (INPE) that has allowed Brazil to join a selected group that provides contributions of climate change statistics to the IPCC's reports. Here we show the first results of the analysis of the Southern Hemisphere (SH) storm tracks under the BESM's RCP8.5 scenario (2006-2104) in the lower troposphere (850 hPa). This is compared with the ERA5 reanalysis dataset (1979-2019). The storm tracks are obtained from an automated feature-tracking technique applied on the relative vorticity field, focusing on the seasonality (summer and winter) of systems that last longer than 2 days and move more than 1000 km. We have found that the zonally symmetric behavior of the SH storm tracks, climatologically observed during the summer, is remained in the RCP8.5 scenario, though there is a shift northwards of its location, leading to an increase (decrease) of the track density from 45°S to 55°S (from 60°S to the Antarctic coast), both in 50%. The asymmetric spiral pattern during the winter is also observed for the storm tracks in the future climate, however the maximum density of mobile storms found near to the Antarctic coast (from 180° to 120°E) is reduced (in 50%), meanwhile it is increased (by 25%) at the south of South America, South Africa and Australia in comparison to the reanalysis. The response of storm tracks to the RCP8.5 scenario is also being done for the other seasons and atmospheric levels.

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First results from Antarctic Modelling and Observational System (ATMOS) Project

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Antarctic Modelling and Observational System (ATMOS) is a scientific project conceived to improve our understanding of sea ice-ocean-atmosphere-waves interactions and turbulent fluxes exchanges, at micro and meso-scales in the Atlantic sector of the Southern Ocean. The expectation is to build an innovative system able to do in situ measurements of atmospheric and oceanic variables. Another goal is develop a regional coupled model of seaice-ocean-atmosphere-waves to understand the physical mechanisms that occur at these interfaces that will fine-tune with observations. Here we present some of first ATMOS year results. On our way to Antarctica we crossed a warm eddy detached from Brazil Current. The vertical profile measurements of the atmosphere and of the ocean, showed that the atmosphere superimposed on warm water becomes unstable, by causing stronger winds over it. Opposite behavior is seen over colder waters outside of eddy core. Together, preliminary results obtained through the wave buoy installed in vicinity of King George Island are presented and compared with numerical simulations carried out for that region. The wave buoy showed two groups of predominant wave systems. The first one from E-SE with peak period (Tp) below 10 s and significant wave height (Hs) around 1.0 m, and the second one from S-SO with higher Tp (above 10 s) and with Hs reaching 3.0 m. The WW3 model simulations followed the oscillations presented by the buoy, underestimating Hs values, probably due to the choice of the atmospheric forcing.

1106

Challenging Antarctic WRF with Satellite-based Cloud and Precipitation Observations via COSP2: Early Results

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Polar clouds and precipitation are fundamental, but poorly understood, meteorological variables with wide relevance to understanding Antarctic climate, including mass balance, the surface energy budget and surface melting.

Satellites carrying active sensors (e.g., CloudSat) provide the only platform with spatial coverage suited to observing precipitation and clouds regularly across the ice sheet. But because of their spatial resolution and temporal sampling, satellite observations are not enough on their own to fully understand these variables.

Regional atmospheric models like Polar WRF offer high-resolution, continuous time series of precipitation, clouds and other related variables but have known skill shortfalls (as do all models, ultimately). By combining remote-sensing observations with modeling, the models can be improved through skill testing/diagnosis. In turn, the verified model supports development of better precipitation datasets and new insights into Antarctic weather and climate variability.

We bridge models and observations using the instrument simulator COSP2 to translate from the modeled atmosphere to products that can be compared directly with satellite-based observational datasets thereby supporting "level playing field" skill testing.

We established our methodology using WRF datasets from the Antarctic Mesoscale Prediction System (AMPS) archive. Because AMPS files are missing some COSP2 input variables, some assumptions and approximations had to be made during this pilot work. Preliminary results from testing the COSP2 CloudSat simulator against CloudSat observations are encouraging but indicate more development is needed before our ideal scenario is viable: production of an improved, long-term precipitation record from new WRF runs.

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Trends in Atmospheric Humidity and Temperature above Dome C, Antarctica Evaluated from Observations and Reanalyses

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The time evolution of humidity and temperature above Dome C (Antarctica) has been investigated by considering observations performed at Dome C from radiosondes since 2005 and from the microwave radiometer HAMSTRAD since 2012. These data have been coupled with reanalyses selected since the end of the 20th century (from 1980 to 2017/2018) from ERA-Interim, MERRA2 and JRA-55, and the southern annular mode (SAM) index over the same period. The observations at Dome C reveal a significant moistening (0.08 ± 0.06 g m-3 dec-1) associated with a significant warming (1.08 ± 0.55 K dec-1) in summer, and a significant drying (-0.04 and -0.05 ± 0.03 g m-3 dec-1) associated with a significant cooling (-2.4 ± 1.2 and -5.1 ± 2.0 K dec-1) in autumn and winter, respectively whilst, in spring, no significant trends are evaluated. Considering the reanalyses, our study showed that 1) the summer moistening/warming and the autumn and winter drying/cooling observed in the beginning of the 21st century agreed with the reanalyses and 2) periods of moistening/warming alternated with periods of drying/cooling whatever the season considered. The decadal trends in Integrated Water Vapour (IWV) and 2-m temperature were obviously anticorrelated to the decadal trends in SAM index for all the seasons but spring. Our study suggests that the decadal trends observed at Dome C since the beginning of the 21st century in humidity and temperature are well within the variability of the atmosphere analysed since the end of the 20th century.

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Observing and modeling snowfall at Dumont d’Urville station, Antarctica, during YOPP special observing campaign : a 3D approach

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Antarctica is the largest reservoir of continental fresh water on Earth: sensitivity to climate change may induce mass balance change and result in significant impact on global sea-level. The surface mass balance of the cap is mainly fueled by precipitation, which is expected to increase by the end of the 21st century according to climate projections. However, there is still limited knowledge and understanding of the processes involved because observations are limited as a results of remoteness and extreme weather conditions.

The OMM project dedicated to improving meteorological research and prediction at the poles (YOPP: Year of Polar Prediction) had a Southen Hemisphere special observing period between November 2018 and February 2019, during which unique observations were made, in particular at the Dumont d’Urville station YOPP supersite in East Antarctica. Models were also run in this framework. In addition to the conventional approach – the surface accumulation of precipitation– the vertical dimension of snowfall is studied, allowing to account for microphysics and dynamics throughout the atmospheric column.

Snowfall occurrences and fluxes from various weather forecast and atmospheric circulation models are evaluated. The use of diagnostics to detect snowing events and of 3 scores exhibits model overestimation both in terms of frequency and intensity. A fair representation of subtle processes such as re-evaporation in the lowest levels even in global models is encouraging but progress is still needed to correctly account for the observations.

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Atmospheric and turbulent fluxes measurements at King Georg Island

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The Atmospheric Modeling Observation System (ATMOS) Project is an innovative project that aims improve the knowledge of sea ice-atmosphere-ocean processes. As part of ATMOS activities is to perform measurements of turbulent fluxes and atmospheric parameters. A micrometeorological tower installed in the coastal region of King George Island made these measurements. Here we present the results from 9 to 23 November 2019 when the research vessel used to deploy these sensors was present in this area in the Bransfield Strait. Air temperature varied from - 3.6 to 6.5 ^{o} C, soil temperature from -0.3 to 7.6 ^{o} C, wind speeds of up to 35 m s-^{1}, with predominant northwest direction, short wave radiation reached values up to 1150 W m-^{2}. The momentum fluxes reached values up to 3.6 Kg m-^{2}s-^{1}, sensible and latent heat fluxes, in most of the period, presented positive values reaching up to 250 W m-^{2}. During the sampled period, the region behaved predominantly as a CO_2 source with an average positive flux of 0.21 µmol m-^{2}s-^{1}. During the campaign we had problems with the load controller, used to manage the solar and battery energy distribution, restricting our sampling this time only during the day. Even with this failure we consider to have a good quality data to study the interaction processes between coastal zone and atmosphere.

1310

Positive trend in regional sea level anomalies and Southern Annular Mode: the southern Brazil analysis

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Pressure gradients and winds play an important role in the regional sea level of the Southern Hemisphere (SH), currently associated with the positive trend of the Southern Annular Mode (SAM) positive trend. Furthermore, projections point to the vulnerability and effects of sea level rise of low-lying coastal countries in the SH. This work investigates regional sea level anomalies (SLA) in the southern Brazil continental shelf (SBcs - 30°–35° S and 49°–52° W) using altimeter data (1993–2019) post-processed by the X-TRACK (CTOH/LEGOS), indicated for coastal areas. We observe negative SLA from 1993 to 2009 and positive from 2010 to 2019, with upward trend throughout the period. We analyse the pressure and wind fields at sea level (ERA 5) and sea surface temperature and height anomalies (SSTA / SSHA - NOAA) in South Atlantic (SAt) in these two periods: 1993–2009 and 2010–2019. In relation to the first period, the second shows the enhance in Hadley and Walker cells and trade winds, in addition to greater SSTA and SSHA in ASt. The ASt subtropical gyre and the zonal winds in 45°S contribute to the intensification of western boundary current. A greater pressure gradient between the SAt surface and the southeast of South America is noteworthy. Regionally, the positive SAM brings an increase in sea level to the SBcs, caused by greater wind stress and variability in heat flows. Thus, we expect an intensification of the current scenario, since the trend of global temperature anomalies and SAM remain positive.

1401

An intercomparison of Antarctic NWP during the Year of Polar Prediction

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The Special Observing Periods (SOPs) of the Year of Polar Prediction present an opportunity to assess the skill of Numerical Weather Prediction models operating over the Antarctic, many of which assimilated additional data made available during these periods through enhanced observational frequency. Hence, the outputs of these models are some of the most observationally-informed to date for the Antarctic, allowing clearer examination of model performance as a result of parameterisation, rather than lack of observations. This intercomparison evaluates several NWP models operating in the Antarctic during a SOP to assess model performance and identify key areas of systematically stronger/weaker performance to inform model development.

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Analysis of high-resolution precipitation and wind events in the Ross Island Region, Antarctic through remote sensing observations

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Studies of high-resolution wind features, and to a much lesser degree precipitation, in the Ross Island region, Antarctica have been investigated through surface automatic weather station observations and numerical modeling. This presentation will investigate the precipitation and high-resolution wind features in the region through remote sensing observations. The observations for this study were collected during the Atmospheric Radiation Measurement (ARM) West Antarctic Radiation Experiment (AWARE) sponsored by the U.S. Department of Energy and National Science Foundation. AWARE occurred from 23 November 2015 to 5 January 2017 and made use of the second ARM mobile facility (i.e., AMF2). The primary AMF2 observing platform employed in this study is the X-band Scanning ARM Cloud Radar (XSACR), which was deployed on the southern tip of Ross Island near McMurdo Station. The focus of the study will be on three precipitation events, each associated with predominantly southerly flow in the lowest 3 km and containing at least 60 hours of widespread radar echoes from XSACR. The remote sensing observations will also be compared to output from the Antarctic Mesoscale Prediction System (AMPS). The comparisons to AMPS will be used to provide a larger understanding of the atmospheric dynamics and circulation and to assess the performance of AMPS in capturing the observed high-resolution features.

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The austral summer atmospheric vertical structure characteristics of Zhongshan Station in 2018-2019

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Using the sounding data and the automatic weather station（AWS）data of the Zhongshan Station Meteorological Station during the 35th Chinese National Antarctic Expedition (CHINARE) in austral summer 2018-2019(Year of Prediction Plan Special Observing Period (YOPP SOP) in the Southern Hemisphere), the atmospheric vertical structure and surface climatic conditions of the Zhongshan Station in the austral summer of 2018-2019 were analyzed. Comparing with the climatic mean, the wind speed , relative humidity and temperature appeared a higher bias, but lower air pressure were observed at Zhongshan Station in summer austral 2018-2019. the average height of lapse-rat e tropopause (LRT) near Zhongshan Station is 8 550 m, and the average height of cold-point tropopause (CPT) is 9 300 m. The corresponding temperatures are –52.8 °C and –55.3 °C, respectively. The corresponding average wind speeds at the top of the troposphere are 18.9 m/s and 16.9 m/s. Compared with the sounding observation data, the NCEP/NCAR and ERA Interim reanalysis data have less error in temperature and a larger error in wind speed. The average performance of the two reanalysis data in the Zhongshan Station area is not much different. Under different weather conditions, the vertical distribution of tropopause height and wind speed is quite different at Zhongshan Station in the austral summer of 2018-2019.

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First efforts of the Antarctic Modeling and Observational System (ATMOS) in coupling the ocean-atmosphere system of the Antarctica through numerical modeling

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Since there are very few in situ measurements systems around Antarctica applied to studies of air-sea fluxes, the Brazilian National Institute for Space Research (INPE) conceived the Antarctic Modeling and Observational System (ATMOS), a project aimed at optimizing our understanding about sea ice-ocean-atmosphere-waves interaction in the Southern Ocean. Using a regional coupled numerical modeling system, we will investigate the air-ocean-wave-sea ice interaction in the Atlantic Sector of the Southern Ocean in order to join efforts to understand the exchanges of heat that occur at the ocean-atmosphere interface under the influence of the presence or absence of sea ice. We will perform two simulations: one coupling the sea ice model to an atmospheric and a hydrodynamic model and another one without the sea ice coupling, using dataset from November, 2019 to February, 2020 and then compare the model output with an deployed buoy and a weather station located at -50.17 ºW, -62.19 ºS. At this location, the buoy is protected from the influence of the Antarctic Circumpolar Current and the data consist of a wind generated waves and ocean swell. Our work is still in progress, since the full dataset is currently being analysed. The influence of the sea ice on the heat fluxes in the Atlantic Sector of the Southern Ocean will be discussed and we expect that our efforts will provide unpublished data to propose physical mechanisms that can explain the role of the ocean and the atmosphere in restoring the equilibrium state of sea ice.

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First results of the Low Cost Atmosphere Measurement Device (LCAMD), developed under Antarctic Modeling and Observational System (ATMOS)

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Antarctic Modeling and Observational System (ATMOS) is a scientific project conceived by the Brazilian National Institute for Space Research (INPE) to improve our understanding on sea ice-ocean-atmosphere-waves interactions of the Southern Ocean. One of ATMOS umbrella projects is to build a system of arduino-based low cost devices to gather data to be assimilated on a regional coupled modeling system. We developed the first Low Cost Atmosphere Measurement Device (LCAMD) prototype in a Pelican Case equipped with a ESP32-DevKitC development board with a DHT22 and BME280 sensors to measure Air Temperature (Tair), Pressure (Patm) and Relative Humidity (RH). In order to prospect LCAMD ability to collect data on extreme weather and climate, we placed our first prototype on Comandante Ferraz Antarctic Station, at the King George Island, at 7 meters high. LCAMD collected data from 14 to 18 February 2020 and we compared the data with a near weather station located at the Chilean Base Frei Montalva President. It was possible to observe the passage of low pressure system through the region, when, at the first 24 hours, the pressure drops from 987 to 981 hPa. Although at the night both compared data showed similar results, during the day we observed a bias in Tair and RH, possible related to LCAMD protection used against radiation and snow/rain. In the future, we plan to facilitate exchange of air inside the device still protecting against severe weather, then develop more devices to deploy in several sites to collect data during the austral summer.

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Climate Variability in the West Antarctica and its Predictability Potential on different time scales

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Assessment of the climate change in the West Antarctic sector (WAS) and its predictability potential mainly for the Antarctic Peninsula (AP) region is the main purpose of the research. El-Nino-Southern Oscillation (ENSO), and in particular El Niño, was found to be responsible for the recent regional climate variability and individual climate extremes. An increase in the near-surface air temperature (SAT) has been peaked at the western coast of AP to the end of 20th century, during the warm ENSO phase. It is shown how the large-scale atmospheric circulation in the West Antarctic sector varies depending on the ENSO phase; the ENSO signal is traced to the lower stratosphere.
The recent warming period is characterized by intensified westerlies and prevailing cyclogenesis within the WAS. Climate after the beginning of the 21st century is characterized by the cessation of surface warming in the AP region, along with changes in the atmospheric circulation, the most important is the increased residence time of its patterns.
A high synchronous and asynchronous correlations are found between SAT anomalies in the AP and set of the oceanic indexes; with the best correlation reached through the East Pacific and South Atlantic index. Statistical forecast schemes for the seasonal SAT for the Antarctic Peninsula stations are obtained. Atmosphere and ocean teleconnections as well as transitions between scales, from large-scale (hemispheric) to regional are showed. Climate projections for the 21st century are developed being based on established links of indexes and teleconnections, growing ENSO influence and geophysical parameters

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Connecting the upper ocean to the atmosphere through ocean waves: a wave buoy mooring at King George Island

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Ocean waves are critical in the coupled atmosphere-ocean system through the enhancement of fluxes of heat, energy and momentum across the air-sea interface and mixing of the upper ocean. Despite the continuous exposure of the Antarctic sea ice cover to energetic storm and wave events from the Southern Ocean there are very limited observation systems present around the Antarctic continent to define the interfacial fluxes and the role of ocean waves therein. To study the role of ocean waves in the air-sea coupled system we deployed a wave buoy mooring at 80-meter water depth near King George Island (62°S 58°W) during the Antarctic Summer from November 2019 till February 2020 in the absence of sea ice. The mooring facilitates observations of the atmosphere, the upper ocean and waves. While sheltered from the Southern Ocean by King George Island, waves in excess of 3 m were recorded and consist of a combination of wind generated waves and ocean swell. As the full data set is currently being analysed, this work is still in progress. The influence of waves on the fluxes of heat and momentum will be discussed and is expected to signify the importance of waves in the air-sea coupled system. More observations of waves around the Antarctic continent are required to further improve our understanding and parameterization of air-sea-wave interactions.

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The Influence of Non-static Sea Ice on the Numerical Weather Prediction

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Antarctic sea ice is an important component of the weather and climate system, modulating radiative and moisture fluxes across the ocean/atmosphere interface and the momentum transfer from the lower atmosphere to the ocean within the higher southern latitudes of the Southern Ocean. These quantities can vary quite rapidly in regions and times of the year where sea ice advances or retreats quickly over large areas (e.g., May – advance, and December - retreat). It is suggested that these quantities are not well represented in Numerical Weather Prediction (NWP) forecasting models when using static sea ice, particularly during times of rapid advance and retreat. In this research, the polar-optimised Weather Research and Forecasting model (Polar WRF) is implemented to investigate how the static sea ice in NWP model impacts the short-term (to +10 days) weather forecast in the whole southern hemisphere, especially the Antarctic region, compared to daily-updated sea ice. In this presentation we quantify the improvement to Antarctic (and lower-latitude) NWP when using more realistic (daily-updating) sea ice fields, and attribute the improvement to various components on the simulated atmosphere (e.g., radiation balance, humidity, cloud, heat flux, etc.). Our results, based on 2018, indicate that inclusion of more realistic sea ice fields into regional NWP should be a priority for national NWP programmes.

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The Southern Hemisphere sudden stratospheric warming of September 2019

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A sudden stratospheric warming (SSW) is observed in the Southern Hemisphere during September 2019, causing the most substantial stratospheric polar warming since 1979. Although the polar night jet did not reverse to easterlies at 10hPa, the polar-cap temperature rose by 70K within approximately three weeks, exceeding that of the 2002 major SSW. The exceptional warming suppresses the formation of polar stratospheric clouds, facilitating the smallest Antarctic ozone hole on record. Diagnostics suggest that this SSW is caused by the enhanced upward propagation of zonal wavenumber 1 Rossby waves from the troposphere, which is the strongest and most persistent on record. The abnormal zonal wavenumber 1 planetary wave behavior is further attributed to a tropospheric wave train emanating from the subtropical Pacific surrounding Norfolk Island and its downstream development. Plausible links between this SSW, tropospheric circulation anomalies and the subsequent bushfires in eastern Australia warrants future investigation.

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Antarctic Atmospheric River Climatology and Impacts

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Atmospheric rivers, broadly defined as narrow yet long bands of strong horizontal vapor transport, provide a sub-tropical connection to the Antarctic continent and are observed to significantly impact the affected region's surface mass balance over short, extreme events. When an atmospheric river makes landfall on the Antarctic continent, their signature is clearly observed in increased downward longwave radiation, cloud liquid water content, surface temperature, snowfall, surface melt, and moisture transport.
Using an atmospheric river detection algorithm designed for Antarctica and regional climate simulations from MAR, we created a climatology of atmospheric river occurrence and their associated impacts on surface melt and snowfall. Despite their rarity of occurrence over Antarctica (maximum frequency of ~1.5% over a given point), they have produced significant impacts on melting and snowfall processes. From 1979-2017, atmospheric rivers landfalls and their associated radiative flux anomalies and foehn winds accounted for around the majority of total summer surface melt on the Ross Ice Shelf and winter surface melt on the ice shelves along the Antarctic Peninsula. On the other side of the continent in East Antarctica, atmospheric rivers have a greater influence on annual snowfall variability. There atmospheric rivers are responsible for 20-40% of annual snowfall while controlling the inter-annual variability of snowfall across most of the region. Many of the moisture or marine air responsible for high precipitation and melting events described in past studies were identified as atmospheric rivers so there are advantages in using the atmospheric river framework to connect these and future events.

Warm-moist air intrusion into the polar regions enhancing cloud longwave radiation and contributing to the warming

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The warm-moist air intrusion from low latitude greatly contributed to the warming in the Arctic (Yamanouchi, 2019). Clouds activated by intrusion together with water vapor and high air temperature increased downward longwave radiation (LD), and contributed greatly to the extreme warming in winter 2015/16 Arctic. This was a part of the mechanism explained by Yoshimori et al. (2017) using climate model. On the other hand, similar increase of LD was found in the occasion of warm and moist air intrusion into the Antarctic. One example of 130 W/m2 increase in LD was found at Dome Fuji Station in 1997, when abrupt temperature rise (+40°C) was caused by the strong ridge due to the blocking formation (Hirasawa et al., 2000), and LD also increased at Syowa Station. Intrusion of warm moist air was just comparable with the Arctic case. Also these intrusions with large amount of water vapor contributed to the accumulation and were called “Atmospheric river”.

Looking at the similar abrupt LD increase in these 20 years (BSRN), most intrusions were not so steep and warming events seemed not so large in the Antarctic compared to the Arctic. Blocking which makes the intrusion deep is rather frequent in the Arctic, and makes the stronger intrusions much common in the Arctic. Also the topography – high ice sheet surface of the Antarctic continent – suppresses warm-moist air mass to penetrate deep into the continent. These might cause the warming suppression in the Antarctic compared to the warming amplification in the Arctic.

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SESSION 5

ANTARCTIC SEA ICE VARIABILITY AND CHANGE: PHYSICAL LINKS WITH THE SOUTHERN OCEAN

Marilyn Raphael

Andreas Klocker, Will Hobbs, Ariaan Purich

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Modeling new ice formation under the influence of ocean waves

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In sea ice modeling the focus has been on the basin to climate scale processes. New ice formation has received less attention. Field observations in the Southern Ocean consistently reported the ubiquity of pancake ice in the marginal ice zone. The presence of this type of ice has also become prevalent in the Arctic Ocean during the fall-winter season. Field observations have also shown that new ice is very effective in damping high frequency ocean waves. Such findings have motivated more refined sea ice models. In this paper, we briefly review the mathematical framework for the new ice formation in sea ice. We then propose an algorithm to expand existing sea ice models to include new ice types in the presence of waves.

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Spatio-temporal variations in snow properties on sea ice in the Weddell Sea, Antarctica

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Snow on sea ice alters the properties of the underlying ice cover as well as associated exchange processes at the interfaces between atmosphere, sea ice, and ocean. As Antarctic snow cover persists during most of the year, it contributes significantly to the sea-ice mass and energy budgets due to comprehensive physical (seasonal) transition processes within the snowpack. However, field studies reveal not only a strong seasonality but also spatial variations from local to regional scales. It is therefore necessary to quantify seasonal snow processes, such as internal snowmelt, snow metamorphism, and snow-ice formation at multiple spatial scales on Antarctic sea ice.
Doing so, we present here a compilation of in-situ observations of physical snow properties on different spatial scales revealed during expeditions in the Weddell Sea since the early 2000s, covering spring, summer, autumn, and winter conditions.
Results from snow pit analyses in the Weddell Sea during both austral winter and spring reveal a high spatiotemporal variability of snow parameters highlighting the need to distinguish between seasonal and perennial snow regimes. Also, the origin of the sampled ice floes and the respective atmospheric conditions experienced must be considered for distinguishing different snow regimes in the Weddell Sea.
Combining data of vertical snow structures from spatially and temporally local measurements (point measurements) with snow accumulation data from ice-tethered autonomous platform (buoys) drifting through the Weddell Sea year-round (trajectory data) allows to investigate seasonal snow processes for the entire Weddell Sea basin.

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Sea-ice growth from the top: Meteoric ice and snow in the northwestern Weddell Sea, Antarctica

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Summer sea ice extent in the Weddell Sea has increased overall during the last four decades, with large interannual variations. However, the underlying causes and the related ice and snow properties are still poorly known.
Here, we present results of the interdisciplinary Weddell Sea Ice (WedIce) project carried out in the northwestern Weddell Sea on board the German icebreaker R/V Polarstern in February and March 2019, i.e. at the end of the summer ablation period, focusing on 21 ice cores sampled for texture, salinity and isotope analysis.
The ice at the coring sites had an average thickness of 178 cm with an average snow depth of 13 cm and a consistently positive freeboard. Isotope and salinity analyses revealed an average meteoric ice fraction of 23%. This included about 17% (22cm) snow-ice, saline sea ice formed by flooding and refreezing of snow at the snow/ice interface. In contrast, superimposed ice, fresh sea ice formed through melting and refreezing of snow only, account for about 6% (11cm) of the sea-ice thickness. Within the study region between 62°S and 66°S, no spatial gradients were apparent. However, this study reveals a higher proportion of superimposed ice compared to previous campaigns in both the same and other areas of the Weddell Sea, indicating changes in the amount of surface summer melt/thaw.
These results highlight the importance of a better understanding of snow accumulation and metamorphism patterns on Antarctic sea ice as it might be a major component controlling the evolution of the underlying sea-ice cover.

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Seasonality of sea-ice and snow properties from autonomous ice-tethered platforms in the Weddell Sea, Antarctica

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Studying seasonally varying snow and sea-ice properties in the ice-covered oceans is a key element for investigations of processes between atmosphere, sea ice, and ocean. A dominant characteristic of Antarctic sea ice is the year-round snow cover, which substantially impacts the sea-ice energy and mass budgets, e.g. by preventing surface melt in summer, and by amplifying sea-ice growth through extensive snow-ice formation. However, substantial observational gaps in the seasonal cycle of the Antarctic pack ice and its snow cover lead to a limited understanding of important processes in the ice-covered Southern Ocean. Here, we introduce a unique observational dataset comprised of a number of critical parameters relevant to sea ice and its snow cover, recorded by a suite of snow and ice-mass balance buoys (IMBs) deployed in the Weddell Sea between 2013 and 2019.
Using snow buoy data, we infer a year-round, mainly event-driven snow accumulation of up to 90cm on the Weddell Sea pack ice, which only melts during the summer months after drifting into the marginal ice zone. Vertical temperature profiles from co-deployed IMBs are used to validate these findings, and to calculate energy budgets across the atmosphere-ocean boundary. From these calculations, we get highest monthly sea-ice growth rates of about 10cm in May, while sea-ice melt is most dominant in the marginal ice zone with a monthly rate of about 50cm in December.
Our results highlight that data from autonomous, ice-based platforms are a key element in better understanding sea-ice and snow properties and their seasonal evolution.

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Climate Response to Projected Antarctic Sea Ice Loss

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Since accurate satellite records began, Antarctic sea ice cover has slightly increased, but with significant regional variation. Antarctic sea ice is projected to dramatically decrease by the end of the 21st century if greenhouse gas concentrations continue to rise. Sea ice plays a significant role in climate of the high latitudes of the Southern Hemisphere, whereby changes may have resultant consequences on the large-scale atmospheric circulation, such as the Southern Annular Mode. Other impacts may include changes to the Meridional Overturning Circulation and consequently, further afield climates. Despite this, limited studies have been conducted on the impacts of Antarctic sea ice loss. Using the UK Met Office HadGEM3 model, we have run a coupled model explicitly simulating the climate response to Antarctic sea ice loss via an albedo feedback mechanism. Results indicate a 'mini global warming' response to Antarctic sea ice loss alone. The Southern Hemisphere dynamic response leads to a negative SAM index associated with an equatorward shift in the westerly jet, agreeing with previous studies. However, results are not only confined to the Southern Hemisphere, but reach as far as the Arctic, causing subsequent Arctic sea ice loss. To determine the atmospheric and ocean pathways, we have also run an atmospheric only model. Here we will propose a mechanism for this cross-hemispheric process and accentuate the importance of using a coupled model.

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Fast ice controls on turbulent mixing rates on the West Antarctic Peninsula shelf

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The ocean surface boundary layer (OSBL) experiences momentum and buoyancy input from the atmosphere, which are strongly implicated in the seasonal development of the mixed layer. However, in polar shelf seas during winter, the presence of a rigid layer of fast ice can render a profoundly different OSBL, where fluxes are strongly suppressed. While the under-ice OSBL has been extensively studied in the Arctic, no study, to the best of our knowledge, has quantified the dissipation rate at the same location under contrasting fast-ice covered and fast-ice free conditions in the Antarctic. In this study, we report on a set of hydrographic and turbulence observations taken in February and August 2016 in Ryder Bay, West Antarctica, alongside accompanying meteorological and velocity observations. The results yield a profoundly different OSBL in the two seasons. Dissipation rates in the top 100 m are strongly enhanced in the ice-free season compared with the fast-ice covered season (values of ~6 x 10-9 W kg-1 compared with ~1.5 x 10-9 W kg-1). Analysis of a neighbouring moored ADCP suggests that this is attributable to a significant increase in wind-generated near-inertial energy in the upper ocean during summer. By contrast, in winter, dissipation in the top 30 m of the water column appears to exhibit a law-of-the -wall type scaling. While the upwards heat fluxes are modest (typically 1.5 W m-2), the rapid reduction in West Antarctic fast ice observed over the last 30 years may lead to a change in the dynamics of the OSBL.

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Summertime winds, seasonal heat storage, and wintertime ice in the southern ocean

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Stronger summertime westerly winds lead to anomalously cold sea surface temperature in the following weeks and months. Here we present a mechanism by which these winds can also cause anomalously warm wintertime sea surface temperatures and a reduction in the maximum wintertime sea ice extent. Strong summertime winds lead to enhanced vertical mixing, which draws heat downwards from the warmer surface waters. At the same time, anomalous atmospheric heat fluxes act to damp the cold sea surface temperature anomalies, drawing additional heat into the ocean. As the mixed layer deepens during the autumn months, the subsurface heat anomalies are brought back to the surface, leading to anomalously warm sea surface temperatures and reduced sea ice extents. Using a combination of observations and models we assess this mechanism in a zonally averaged context, and speculate about its importance regionally.

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The asymmetric seasonal cycle of Antarctic Sea Ice in the CESM Large Ensemble

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Each year, Antarctic sea ice takes seven months to grow to its maximum extent but only five months to melt. Wind-driven Ekman transport has been suggested as a key mechanism driving this asymmetry with the direction of the Ekman transport depending on the position of the ice edge in relation to the circumpolar trough that circles the continent between 60° and 70°S. During autumn, easterly winds act to slow the advancing ice edge, whereas in summer, Ekman divergence, created by opposing winds on either side of the low-pressure band, opens up warm water regions that rapidly melt sea ice. However, this mechanism has so far not been quantified.

We examine the relationship between asymmetry in the annual cycle of sea ice extent and the position and intensity of the circumpolar trough in the 40 ensemble members from the CESM-LENS historical run (1920-2005). CESM-LENS reproduces the annual cycle of sea ice extent well and these outputs are a useful tool for investigating the variability of the annual cycle. We find the greatest variability in melt rates, whereas growth rates remain consistent. We show that deepening of the circumpolar trough leads to increased melts rates, thereby supporting the role of divergence in increasing the rate at which Antarctic sea ice melts. The role of winds versus the stabilizing effect of the ocean during the growing season remains unquantified.

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An idealized model to simulate different scenarios of ocean, atmosphere and sea-ice interactions

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The interaction between atmosphere, ocean, and ice plays a significant role in global sea-level rise, an essential area of climate change research. The growth and melt of Antarctic sea-ice occur as a result of ocean-atmosphere exchanges of heat, momentum, and freshwater as the combination of the ocean and atmosphere circulation. However, the sea-ice cover variations are not a passive phenomenon but a variety of positive and negative feedback effects among those three components. Exploring the sea-ice dynamics and ocean-atmosphere interaction is crucial to understanding the Antarctic climate system and, therefore, the global climate system. Ocean-ice modeling highlights the sea-ice biases as a significant contributor to the uncertainties in future predictions over Antarctica, ice sheet mass balance, and sea-level rise. We developed a controlled idealized domain over the Southern Ocean, aiming to identify the interaction of the different processes driving the sea-ice melt and growth annual cycling. Our ocean-ice numerical model was developed using Regional Ocean System (ROMS) with Budgell sea-ice thermodynamics and consists of a generic ocean with topographic and ocean features common to the Southern Ocean forced by atmospheric climatological fields (pressure and temperature) and completely geostrophic winds. The model evolution can prognostically calculate ice concentration and thickness and produce a feedback response that changes the ocean-air exchange of heat. Based on that, several scenarios were created to identify mechanisms through which the sea-ice dynamics are affected (and affect) by the ocean and the atmosphere.

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Antarctic Sea Ice Extent Reconstructions during the 20th Century

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Antarctic sea ice plays an important role in climate variations across the continent, as well as globally through connections in the ocean. Yet, little is known about the range of Antarctic sea ice extent variability prior to the modern satellite era of 1979. Indeed, the dramatic rapid decrease of Antarctic sea ice in 2016 after decades of increase demonstrates that the Antarctic sea ice system has marked variability that we do not fully understand.
This presentation will evaluate preliminary reconstructions of Antarctic sea ice extent based on a linear statistical model, principal component regression. Two sets of reconstructions will be analyzed, including a monthly reconstruction that employs Antarctic station data as a predictors as well as midlatitude data, but only extends back to 1957, and seasonal reconstructions based primarily on midlatitude predictor data that extend back to 1905. The skill of these reconstructions will be demonstrated through independent validation techniques, and the range of historical sea ice variability, including the recent change, will be evaluated on much longer timescales. Such work helps to increase the understanding of Antarctic sea ice variability and change and has implications for research in Antarctic atmospheric science, the Antarctic cryosphere, the climate modeling community, as well as the Southern Ocean.

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The influence of mixed layer dynamics and ice-ocean feedbacks on the seasonal cycle of Southern Ocean Sea ice

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The seasonal cycle of the sea ice extent in the Southern Ocean is strongly asymmetric with a relatively slow increase followed by a more rapid decrease after the winter maximum. This asymmetry is strongly conditioned by the changes in winds and more generally by the atmospheric forcing. Nevertheless, the evolution of the mixed layer depth and of the ocean-sea ice heat flux is also very different between the growing and retreat seasons, with generally higher upward heat fluxes in fall when the mixed layer is thickening. Furthermore, the evolution of the mixed layer is not independent of that of the sea ice, as the surface layer dynamics are controlled by the brine released during ice formation. This role of ocean surface dynamics and ice-ocean interactions in the seasonal cycle of the ice extent is investigated here using several simulations obtained with a new eddy-permitting (1/4°) NEMO-LIM Southern Ocean configuration including ice-shelf-cavities. Specifically, the mixed layer depths and ice-ocean feedback are frozen in sensitivity experiments to quantify the contributions of the various processes.

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Antarctic Sea-Ice Decadal Variability since 1980

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It has been nearly four decades since Sea-ice extent (SIE) satellite data started being stored and studied. I will present a new approach for the SIE statistical distribution to examine decadal changes as a function of season for each regional sea around Antarctica using Probability Density Function (PDF).
The presentation follows an article, written by me and other researchers, sent to submission on the Journal of Geophysical Research this January 2020, exploring the SIE data from National Snow and Ice Data Center (NSIDC). Where the results show a significant decadal difference in the SIE normal PDF between both the Weddell Sea sector (48% of differing data distribution between 1982-1993 and 2006-2017) and the Amundsen-Bellingshausen (55%) for Austral Summer. These two Sea sectors is where most of the Southern Ocean SIE variability occurs (Weddell representing 61% from the SIE growth and Amundsen-Bellinghausen the only sector presenting a SIE decrease). In Spring the largest contribution to SIE growth is seen in the Ross Sea (43% differing data from 82-93 to 06-17). The largest decadal differences in data distribution from 82-93 to 06-17 of the Southern Ocean is observed in Austral winter, where all individual Sea sectors present a SIE growth.

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Wave modulation of the Antarctic marginal ice zone extent

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The Marginal Ice Zone (MIZ) is the highly dynamic outer belt of partially ice-covered ocean formed by unconsolidated or broken ice where ocean waves, atmosphere, and sea ice processes are closely interlinked. This belt is operationally defined as the region where sea ice concentration falls between 15 and 80 percent. Like consolidated sea ice, also the MIZ plays a pivotal role in the global climate system by altering fluxes of energy, mass, and momentum between the ocean and atmosphere as well as modifying the ocean surface albedo. Knowledge of the extent of the MIZ and processes modulating it are fundamental for climate predictions. Long term satellite data records provide an extensive database for the investigation of the MIZ and its extension and variability. Here we will discuss the correlation between ocean surface waves and the extent of MIZ. To accomplish this task a database of sea ice concentration from the Ocean and Sea Ice Satellite Application Facility (OSI-SAF) and Advanced Microwave Scanning Radiometer (AMSR-2) as well as altimeter observations of significant wave height and wind speed obtained from the Australian Ocean Data Network (AODN) will be used. Both data-sets cover a period of 34 years spanning from 1985 to 2019. Results indicate that the MIZ extent is modulated by wave height with large extents occurring in months of energetic wave regimes.

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Sea-ice lead climatology for the Antarctic based on MODIS satellite data

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Sea-ice leads are characterized by open water and thin ice causing large energy and moisture fluxes between ocean and atmosphere. Furthermore, they contribute to the ice production and provide a habitat for animals. In the present study, thermal satellite data from the Moderate Resolution Imaging Spectroradiometer (MODIS) are used to derive Sea-ice lead climatology for the Antarctic for the winter periods 2003–2018 (April–September). This study presents the first high-resolution climatology of sea ice leads for the Southern Ocean. The long-term average lead frequency distribution suggests a strong relationship between leads, bathymetry, and associated tides and currents. These findings are supported by coupled ocean-sea ice model simulations. In particular, pronounced patterns associated to the shelf break and several seabed ridges are detected.

1175

Re-evaluating the Conventional Definition of the Marginal Ice Zone for the Antarctic

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In polar regions, sea ice is a key factor modulating physical and biogeochemical exchanges between the ocean and atmosphere. The marginal ice zone (MIZ) is particularly sensitive to rapid variations in ocean and atmospheric drivers, which poses a challenge for its proper inclusion in climate models. The MIZ is conventionally defined as 15% to 80% sea ice concentration (SIC). Here, we provide direct evidence that challenges this concentration-based definition through a combined analysis of in-situ, satellite, and reanalysis data. SIC observations were made in winter 2017 and 2019 onboard the R/V S.A. Agulhas II to verify satellite and reanalysis SIC estimates in the Atlantic sector. We used the Antarctic Sea Ice Processes and Climate (ASPeCt) protocol complemented by software-based, automatically-acquired SIC to account for the subjective bias inherent in ship-based observations. The Antarctic winter MIZ was dominated by pancake ice with frazil ice located in the interstices between the individual pancakes. These MIZ conditions were observed for 150–200 km while the remote sensing MIZ was less than 90 km. Most observations recorded pancake ice cover of 50% to 90% SIC and total ice cover (pancake and frazil ice) of 100% SIC. Our data indicates that there is a discrepancy between the concentration-based MIZ definition and the observed surface characteristics of the MIZ during its advancing phase. The MIZ appears to cover larger distances than what is predicted from satellite observations. This extended cover may have implications on surface fluxes through ice, impacting the Antarctic MIZ's representation in climate models.

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The dynamics of Southern Ocean and sea ice response to different anthropogenic forcings

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The high latitude Southern Ocean's response to anthropogenic forcing is a complex interplay of wind and radiative changes at the surface, modulated by the ocean's overturning circulation, and by ocean-sea ice feedbacks. The response to greenhouse gasses and stratospheric ozone depletion is expected to be subtly different, which has implications for projected change as their relative importance changes over the coming decades. Therefore, to constrain projections, a mechanistic understanding of how the ocean-sea ice system responds to them individually is essential.
However, isolating the physical mechanism of this response is complicated by the low signal-to-noise ratio of much of the Southern Ocean (i.e. the signal of climate change is small compared to the high internal variability of the system).
To address this issue, we analyse output from single-forcing experiments in the CESM Large Ensemble. We find that the pattern of wind responses to these forcings is quite similar, but the seasonality is different. This has implications for the ocean's response, and suggests that over the historical period greenhouse gasses may have been a more important factor on Southern Ocean circulation change than ozone depletion.

553

Recent sea ice and climate variability in East Antarctica

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Antarctica's sea ice cover is an important component in the global climate system. The variability and recent trends in sea ice concentration are, however, not accurately reproduced by models. This is in part because the processes that determine sea ice distribution are not yet well understood, particularly in the East Antarctic region. With the growing recognition that areas of East Antarctica such as Wilkes Land are more vulnerable to climate change than previously assumed, further research into the drivers of sea ice variability is needed to enable accurate projections of how Antarctic sea ice and climate is likely to change in the future. Here we investigate the effects of climate variability on recent sea ice concentration around East Antarctica by examining the HadISST 40-year (1979-2018) satellite sea ice concentration record and ERA5 atmospheric reanalysis data. Preliminary analysis of the Wilkes Land region shows that sea ice variability was linked with the Indian Ocean Dipole (IOD), where negative IOD phases were associated with reduced sea ice concentration in austral spring, and also to sea surface temperatures (SST) in the equatorial Indian Ocean, along with the Southern Annular Mode (SAM). Further analysis will examine the mechanisms by which these links occur, and the extent to which they may affect change in the East Antarctic Ice Sheet. This will allow for a better understanding of the influence of atmospheric variability on the East Antarctic cryosphere, and lead to more accurate modelling of sea ice extent in the Southern Ocean.

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Satellite observation of a large open ocean polynya on the Maud Rise seamount

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Open-ocean polynyas are the regions of open water within the seasonal sea-ice cover, occurs away from the shore. The occurrence of such polynya is known to have consequence on the Antarctic bottom water propertie, atmospheric circulation, Antarctic marine ecosystem, carbon uptake and primary production. Satellite observations show that a large and most prolonged Maud Rise polynya (Lazarev Sea), reappeared on 14 September 2017 for the first time since its frequent appearance during the 1970s. On 14 September 2017, the areal extent of the polynya was ~9.3 × 103 km2 which expanded maximum on 1 December 2017 up to ~298.1 × 103 km2, lasting for 79 days. The formation of the polynya was due to the combined influence of the (i) existence of the geological features such as seamount (leads to local upliftment of thermocline), (ii) upwelling of warm water into the upper ocean from the thermocline (induced by a large cyclonic ocean eddy and negative wind stress curl), and (iii) the large-scale anomalous atmospheric warming. The mechanism of polynya formation in 2016 was similar to that of 2017.

729

Evaluation of the crystal structure of Antarctic Sea Ice from the Marginal Ice Zone from winter and spring 2019

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The South Atlantic Marginal Ice Zone (MIZ) is a region of the Southern Ocean that has historically been under-researched with its sea ice being inaccessible during the winter and spring months. Sea ice crystal structure and stratigraphy has been widely researched and is well-understood across many regions and ice types. However, studies have not shown how sea ice crystal stratigraphy may differ with seasons in a region, as well as how weather and climate systems definitively may affect it. Additionally, pancake sea ice and its stratigraphy has not been reported due to the difficulty of in-situ testing of the structures. The research to be presented aims to describe the difference in Antarctic sea ice in the South Atlantic MIZ collected in the winter and spring of 2019 at different locations. This includes describing the crystal stratigraphy of pancake ice, consolidated ice and brash ice, which will be carried out using cross-polarisation techniques. Additionally, it is hypothesised that the intensity of passing low pressure systems affect the resulting crystal stratigraphy of the sea ice in the region, by inducing a deformation process that can lead to granular ice found at unusual depths in the sea ice.

1208

Southern Ocean circulation and Antarctic sea ice in a global coupled ocean-sea ice model at three resolutions

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ACCESS-OM2 is a suite of three global coupled ocean - sea ice model configurations at 1, 0.25 and 0.1-degree horizontal resolution, consisting of the MOM5 ocean model coupled to the CICE5 sea-ice model and driven by a prescribed atmosphere (JRA55-do). We will present a comprehensive assessment of the performance of these configurations relative to available ocean and sea ice observations in the Southern Ocean and Antarctic, highlighting the improvements we obtain at increased horizontal resolution. We will also discuss the ability of these models to represent sea ice trends, including the recent decline in Antarctic sea ice extent.

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Ocean-ice interaction in subpolar Southern Ocean generates internal pycnocline

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The internal pycnocline delineates the interface between the wind-driven circulation in the upper $\sim$1000 metres of the ocean, where most of the global ocean uptake of heat and anthropogenic carbon takes place, and the sluggish abyssal circulation below. While ocean observations robustly show the existence of the internal pycnocline, to date our knowledge about the dynamics leading to the generation of this interface is very limited. Here we show that the internal pycnocline is generated by upper-ocean processes in the subpolar Southern Ocean. The internal pycnocline layer integrates multiple high potential vorticity (PV) sublayers that emerge at the base of the winter mixed layer in different regions of the Southern Ocean. The high-PV layers are produced via ocean-sea ice interaction. As the internal pycnocline layer lies within a density class characterised by zero residual flow, the pycnocline's high-PV signal is inferred to propagate northward from the subpolar Southern Ocean via diffusive processes. This process points towards the crucial role of ocean-sea ice interaction in setting the vertical structure of the ocean.

659

Wind-driven Sea-Ice Change intensifies subsurface Ocean Warming near West Antarctic

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Climate change observed around Antarctica in recent decades is characterized by distinctive zonally-asymmetric patterns, most pronounced over West Antarctica. The change is evident throughout the cryosphere, marked by land ice melting, thinning of ice shelves, and sea-ice redistribution around West Antarctica, associated with temperature and circulation anomalies in the atmosphere and ocean. Here we examine the links between these changes using observations and numerical simulations. Results show that atmospheric circulation change drives variations in sea-ice distribution and ocean circulation. Most importantly, sea-ice variability alters the efficiency of the ocean's salt pump, driving sub-surface ocean warming and sub-surface salinity increase around West Antarctica through changes in surface salinity and freshwater fluxes. This sub-surface warming may potentially contribute to West Antarctic land ice melting, with important implications for global sea-level rise.

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The Ocean's role in driving Antarctic sea ice variabilities

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Antarctic sea ice processes strongly interact with the atmosphere and the ocean. The changes occurring in sea ice affect the ocean, which could lead to long-lasting effects that can further impact the sea ice. The annual cycle of sea ice influences the formation of bottom and intermediate water masses, which is relevant in the absorption of carbon and heat into the ocean. Hence the changes in sea ice have an effect on global heat and carbon budgets.
In this study, we look at the impact of ocean-sea ice interactions on sea ice trends and predictability using satellite sea ice data from 1985 to 2016. The analysis confirms previous studies showing that spring sea ice is related to anomalies in subsequent seasons. Furthermore, we identify regions of 'persistence', where anomalies continue throughout the summer and autumn, and 're-emergence', where anomalies disappear in summer but re-emerge in autumn. Almost all regions have re-emergence, which is stronger in Ross and Weddell seas. Analysis conducted using the ocean-sea ice model (ACCESS-OM2) also produce persistent and re-emergent patterns. To better understand the physical processes driving these re-emergence and persistence patterns, we will analyse a high-resolution ocean-sea ice model.

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SIPN-South: Coordination of sea-ice predictions for the Southern Ocean

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The Sea Ice Prediction Network's endeavours are expanded to the Southern Ocean by the SIPN-South project. We provide a focal point for seasonal Antarctic sea-ice predictions to the community and offer a platform for interested parties to openly discuss methods and results and assess model performance against observations based on passive microwave remote sensing data. We have completed two exercises to forecast summer sea-ice conditions during the Year Of Polar Prediction and are continuing on with a third season in 2019/20. It is envisaged that the project will continue and expand.

In this paper, we will present results from the three already completed austral summer sea-ice predictions and discuss the outcomes, including comparison against satellite data. While we acknowledge that the models that participated in the exercises so far are not yet employed for operational predictions, it is our goal to facilitate discussions and potentially inform decision processes when forecasting summer sea-ice conditions in the Southern Ocean.

1561

Antarctic Sea Ice variability in connection to local and remote forcing

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In-spite of global warming, the Southern Hemisphere (SH) is the only cryospheric domain that portrays a positive long-term trend in sea ice extent (SIE, 2.61±2.34%/decade) and seasonal (summer 1±0.94%/decade, autumn 3.53±0.31%/decade, winter 1.04±0.46%/decade and spring 0.94±0.46%/decade), over the 1979-2018. The Ross Sea (2.11±1.32%/decade), Indian Ocean (1.25±1.40%/decade) and Pacific Ocean (1.89±1.57%/decade) also had positive trends, while the Bellingshausen & Amundsen Seas (-2.43± 1.91%/decade) exhibits negative trends, and the Weddell Sea (0.81±1.11 %/decade) experience a mixture of positive and negative trends. Since 2014, the sea ice extent has exhibited a dip (-4.2±3.4%/year). Local forcing factors like winds, sea surface (SST) and air temperature (Ta), and turbulent heat flux (TF) and teleconnections like Southern Oscillation Index (SOI), Pacific Decadal Oscillation (PDO), Atlantic Multidecadal Oscillation (AMO), and Southern Annual Mode (SAM) were examined over each decade (1979-1988, 1989-1998,1999-2008, 2009-2018) using Pearson correlation for each of the five sectors. For entire SH, SST, Ta, AMO were highly correlated to SIE during 2009-2018, compared to earlier decades. For Weddell Sea and Indian Oceans, SST and Ta was highly correlated to SIE, while for Pacific Ocean sector only Ta is high correlated, for all decades. SST and Ta were found to be high correlated with SIE for Bellingshausen & Amundsen Sea for all decades. For the Ross Sea SST & Ta are negatively correlated to SIE during 2009-2018. PDO was negatively correlated to SIE during 1979-1988 which switched sign during 1989-2008 for Weddell Sea. The role of local forcing dominates SIE in the last decade.

1516

Understanding the Relationships between Sea Ice Extent Variations and Surface Winds at Multiple Temporal and Spatial scales

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This presentation describes progress towards understanding how winds influence sea ice and whether the relationship between sea ice and winds vary at different temporal and spatial scales. The aim of this work is to quantify the sensitivity of sea ice concentrations to surface winds and whether there are thresholds associated with the wind speeds or other factors which must be passed for different sea ice regions to respond to these winds. The relationships to high and low frequency variations are also examined specifically and the underlying physical processes which explain these responses. To analyse these processes, we examine the Bootstrap sea ice concentration (SIC) satellite data set derived from SSM/I brightness temperatures and how they are connected to surface winds from the ERA5 reanalysis over the period 1979 to 2018. While analysis is completed over the entire sea ice zone around Antarctica, special attention is paid to the Ross Sea region and the Ross Sea Polynya. In particular, a range of machine learning schemes are tested to determine whether they can be used to identify spatial regions in which sea ice responds to winds coherently.

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Antarctic sea ice budgets in ACCESS-CM2 model compared to other CMIP6 models.

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The ACCESS-CM2 model has a realistic Southern Hemisphere sea ice extent and area in winter in the historical and pre-industrial control simulations but too little ice in summer. The model's ice thickness is too thin compared to the limited shipboard observations that exist in the ASPeCt data set. We have compared these results with the sea ice results in ACCESS ESM1-5 which were similar to the results from the CMIP5 model ACCESS1-3. All three models have a warm bias in the Southern Ocean sea surface temperature (a common feature in many climate models) which contributes to the summer ice extent bias seen in ACCESS-CM2.
For SIMIP, a project of CMIP6, additional diagnostics have been saved that allow us to investigate the sea ice budget: components that lead to ice growth (frazil, basal, snow ice), melt processes (top, basal, lateral), loss due to sublimation and ice advection. There has already been an inter-comparison study on these SIMIP budget terms on the Arctic region. Here we undertake one for the Antarctic and for key regional sectors of the Antarctic, where the response is due to different atmospheric and oceanic drivers.
We compare ACCESS-CM2 results with selected CMIP6 models that also have a full set of data of the required budget terms, available through the Earth Systems Grid, and that produce a realistic winter sea ice maximum extent and some summer sea ice coverage.

1519

Sea ice state along the Victoria Land Coast, Western Ross Sea, characterized by airborne and satellite measurements in spring 2017

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Direct assessment of the sea ice mass balance requires information about ice thickness, which is a major uncertainty in Antarctic sea ice studies. We aim to establish a relationship between satellite derived trends in sea ice cover and region-wide ice thickness distribution. In 2017 we conducted airborne measurements over pack ice, partly along CryoSat-2 satellite altimeter tracks, to assess sea ice morphology between Ross Island and Cape Adare. Our objective is to shed light on geophysical processes which allow to better explain the complex sea ice structure in this important region of net sea ice production. As our main instrument we used an airborne electromagnetic induction sounder, which is deployed from a DC-3 aircraft simultaneously with a lidar and camera.

We present the results of our survey flights in combination with a satellite data assessment to characterize the sea ice morphology in the area. For our statistical analysis of the pack ice conditions we take into account the sea ice drift pattern during the airborne observations. Strong ice thickness gradients have been observed from the polynya regions towards the central Ross Sea as a result of thermodynamic growth. Ice is then heavily deformed in export regions of the McMurdo Sound and Ross Sea polynya where it converges with ice originating from Terra Nova Bay. Variations in modal thickness are identified as various stages of deformed ice. An improved picture of the formation history and current state of the sea ice the Western Ross Sea is drawn.

733

The Annual Cycle of Antarctic sea ice extent: the influence of the Semi-Annual Oscillation on phase.

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The annual cycle of Antarctic sea ice extent is asymmetric. On average, total Antarctic sea ice extent expands (advances) for approximately seven and a half months, from late February to late September, and contracts (retreats) for four and a half months each year. While other factors may influence the size of the extent, previous research suggests that the timing of the growth and retreat stages, also called the phase, is in part due to the influence of the semi-annual oscillation (SAO) of the Antarctic circumpolar trough (Enomoto and Ohmura, 1990; Watkins and Simmonds, 1999). Using observed daily sea ice extent, we create and evaluate a timeseries of the phase of Antarctic sea ice over the period 1979-2018. Using sea ice concentration, sea level pressure, and winds, over the same period, we compare the strength and timing of the observed SAO and the related winds with the variability of the observed phase of the annual cycle and the breakup of ice within the pack. The results are used to help understand the anomalously rapid sea ice decay which occurred in 2016.

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What we can learn from a year of sea ice

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Antarctic sea ice is an integrator of ocean, atmosphere and cryosphere climate elements and reveals facets of these climate systems and their interactions that are otherwise difficult to observe. Here we examine these interactions with a focus on the regional and seasonal variability of sea-ice cover and associated drivers. We use and expand on the analysis from the most recent Bulletin of the American Meteorological Society's State of the Climate Antarctic sea ice report for the year 2019, while briefly putting this into historical perspective. We cover the large-scale drivers of sea ice, setting the regional variability into context with long-term trends. Factors considered include tropical drivers (high-low latitude interaction), cross-cryosphere interactions, and sea-ice momentum. We also touch on the influence of transient cyclones on the position of the sea ice edge.

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Upper ocean properties around the South Orkney Islands, Antarctica, in two years of contrasting sea ice conditions

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The South Orkney Islands and the surrounding plateau, situated in the Weddell Scotia Confluence between the Antarctic Circumpolar Current and the Weddell Front, are a highly productive and important region for the ecosystem in the Atlantic sector of the Southern Ocean. A hotspot for Antarctic krill, the region is a key fishing ground for the commercial krill fishery. Processes influencing the advection and retention of krill around the South Orkneys have impacts not only locally, but across a wider region downstream. The circulation around the South Orkney Plateau is dominated by a topographically steered boundary current which transports surface and intermediate water masses along the shelf break. In this study, we present observations from two hydrographic surveys across the plateau in 2016 and 2019. These two years were characterized by opposing patterns in the sea ice coverage prior to the surveys, and the large-scale climate state linked to El Niño. We analyse water mass properties and transformations along the pathway of the boundary current and explore linkages to sea ice and the atmosphere through freshwater input from ice melt and sea surface temperature anomalies. Particular focus is on the northern edge of the plateau and a canyon situated on the northwest of the plateau, in which large krill aggregations frequently occur.

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Where is it and what is it doing?

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A precise knowledge of the thickness of sea ice is important for: estimating sea ice volume; determining mechanical strength; understanding light penetration; and monitoring the sea ice growth and decay. However, defining the underside of the ice is not straightforward, for example in McMurdo Sound, Antarctica when a sub-ice platelet layer is present. The friable sub-ice platelet layer consists of ice platelets of seemingly random orientation under the consolidated sea ice. Thermistor strings are commonly used to observe sea ice thickness over long time periods and different methods of processing thermistor data are found in the literature. So far, there is very limited understanding of the uncertainties associated with estimating sea ice thickness from thermistor strings. This makes it difficult to quantify natural variability and assess whether changes are part of a long-term trend. We present an analysis of sea ice thicknesses calculated from thermistor strings deployed in McMurdo Sound over two decades. We compare different methods of processing the data to determine the ice-ocean interface and investigate the robustness, precision and accuracy of these methods. The results are compared to other acoustic/mechanical methods and locations. The resulting 20 year thickness time-series provides the rare opportunity to quantify interannual variability and study existing or emerging trends in McMurdo Sound sea ice whilst talking into account the uncertainties introduced by the methods. The aim is to make it easier to analyse and compare observations, and assist in constraining the range of variability and the rate of change in sea ice thickness.

1698

Investigating ocean and atmosphere anomalies on and off the Ross Sea continental shelf to help explain persistent low sea ice in the Ross Sea since spring 2016

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Several mechanisms have been previously proposed to explain the record-breaking low sea ice extent in the Ross Sea in spring 2016, including the high latitude response to tropical forcing, combined with internal & regional atmospheric variability (e.g., zonal wave 3, SAM), as well as persistent ocean thermal anomalies operating at seasonal to decadal time scales. This record low spring sea ice extent in the Ross Sea was particularly noteworthy since it stood in stark contrast to the strong positive sea ice extent trends previously observed in all seasons in the Ross Sea (though strongest in autumn and spring).

Remarkably, since spring 2016, the Ross Sea continues to experience anomalously low sea ice extent. Here we explore autumn-winter ocean data acquired during PIPERS (Polynyas, Ice Production and seasonal Evolution in the Ross Sea) in 2017 to explore both ocean (e.g., anomalous surface/sub-surface ocean heat and water mass distribution) and atmospheric (e.g., anomalous wind/wave and surface solar heating) processes that may have contributed to the anomalously late autumn-winter ice edge advance and thickness evolution in 2017. We also highlight potentially different mechanisms that may be operating on and off the continental shelf as well as seasonally. Finally, the 2017 ocean and atmospheric conditions are compared to available historic data to explore potential explanations for the multi-year persistence of low sea ice in the Ross Sea since spring 2016.

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Sea ice and tidal rectification drive the Antarctic Slope Front

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The Antarctic Slope Front (ASF) separates the cold waters of the Antarctic continental shelf from the warmer waters of the Southern Ocean. Previous studies have explained the ASF as a result of wind-driven Ekman transport toward the coast, but have largely overlooked two key drivers of the circulation: (i) sea ice, which mediates momentum input to the ocean, and (ii) acceleration of the along-slope flow by tidal motions.

In this presentation we first investigate the momentum balance and overturning circulation of the ASF using a high-resolution (1/48th degree) global ECCO2 ocean/sea ice simulation. Over the continental slope, we show that surface stresses associated with sea ice drift accelerate the ocean flow westward, and the resulting Ekman overturning circulation serves to steepen the ASF. In contrast, over the continental shelf break we find that tides accelerate the flow to a similar speed as the overlying sea ice, such that the surface stress approximately vanishes. Consequently tides, rather than surface stresses, drive the overturning circulation that steepens the ASF at the shelf break.

To elucidate this interplay between tides and sea ice in the ASF, we conduct process-oriented high-resolution simulations with varying sea ice thicknesses, tidal amplitudes, and cross-slope buoyancy gradients. We find that ice-ocean drag and tidal rectification primarily control the barotropic component of the along-slope flow, while cross-slope buoyancy gradients primarily set the baroclinic structure of the ASF. These findings therefore revise current understanding of the processes that set the ASF's density structure, ocean transport and sea ice drift.

1714

The role of Antarctica sea ice on modulating the Primary Productivity in the Southern Ocean

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Chlorophyll concentration (Chl-a) is a primary proxy for primary productivity in the oceans. Various physical and biogeochemical parameters are known to govern Chl-a. In the Southern Ocean, sea ice is known to be one of the major factors affecting the regional temperature of the ocean and hence its primary productivity. Hence, analyzing the variations in regional sea ice extent in this region would assist in understanding the Chl-a, and hence primary productivity. Further, sea ice is also quite sensitive to the effects of climate change. The sea ice extent and corresponding Chl-a variability in the Southern Ocean have been studied in this work utilizing more than 35 years remotely sensed sea ice data and about 15 years of Chl-a and Sea Surface Temperature observations. It was found that the offshore katabatic winds blowing from the Antarctic coast enhances the sea ice extent during winter, while diminishing the sea ice melting in the summer. The Weddell region shows the highest sea ice extent of 3×106 km2 during summer, where as other regions show a sea ice extent of less than 1.9×106 km2, where the wind blows alongshore or towards the coast. The vertical structure of various bio-physical parameters in the Southern Ocean as available from few Bio-Argo floats in the study region were also examined which revealed the nutricline in the region to directly affect the Chl-a distribution.

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Reconsideration of snow effect on growth and preservation for Antarctic multi-year landfast sea ice

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Long-lived perennial sea ice, or multi-year ice (MYI), has been formed near the front of ice sheet and glaciers. Landfast MYI has a buttress role for glaciers and a factor affecting variability of ocean-glacier subsystem. Satellite observations suggest that MYI has existed for over 30 years in Lützow-Holm Bay near 39E in East Antarctica. Under heavy snow condition, sea ice is supposed to be upward thicker through formations of snow ice and/or superimposed ice. Even in much snow, sea ice has not grown indefinitely, according to an airborne-EM measurement data. MYI existence contributes to landfast ice stability. Stable or unstable regimes for landfast ice in the bay have been alternately repeated since 1980 with several to ten years interval. Interannual variability of snow accumulation as well as events of ice breakup have been examined together the analysis of ice core. Note that snowpack gives opposite effects on preservation of ice; one is mechanically reinforcement by thickening through upward-growth and high albedo; the other is weakening due to lowering flexural strength by increasing the ratio of snow-origin ice. There is no doubt that the snowpack has affected strongly physical modification of ice body. A growth history of sea ice is reflected in physical and biogeochemical characteristics, such as ice texture, salinity, and stable isotopic structures of the core sample. An ice sample has been collected with 3.86 m in length near the Shirase Glacier in 2018/19 season. We report the in-situ drilling operation and show features of sea-ice structures.

1267

Air-sea-ice interactions at the mesoscale : case study of the Mertz Glacier Polynya in a regional climate model.

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The Mertz Glacier Polynya, in east Antarctica, is a limited area of the Southern Ocean, which is often free ice even during the austral winter. The absence of sea ice in the polynya allows for intense exchanges of heat, moisture, and momentum between the cold and dry atmosphere and the relatively warmer ocean. Despite being paramount features of the polar climate, little is known about the processes taking place between the ocean, ice and atmosphere in polynyas. Here, we describe the dynamics of the Mertz Glacier Polynya using a high resolution regional coupled model of the ocean, sea ice and atmosphere (NEMO-LIM 3.6 and MAR). We describe the daily to seasonal variability of the polynya activity and air-sea fluxes during years 2012-2013. We then assess the impacts of the polynya on the formation of Dense Shelf Water and basal melt of neighboring ice shelves. We also analyze the response of the atmosphere to the presence and variability of ice free area. To assess the effect of potential feedbacks, we conduct a second set of experiments in standalone forced mode. Finally, we perform an experiment using the coastline prior to the Mertz calving in 2010, to test the sensitivity of air-sea-ice interactions to drastic changes in polynya activity. This work improves the understanding of the exchanges taking place in polynya together with their impact on regional polar climate. It also represents a further step in the representation of polar regions in climate models.

1064

Using historical whale catch data to evaluate climate model results in the Southern Ocean

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The assessment of historical climate model simulations in the Southern Ocean is limited by the availability of oceanographic records during the 20th century until remote sensing observations. Whale catch data can help to fill this gap, because they represent a wealth of information on the habitat distribution of commercial whales and the underlying environmental conditions. Although the impact of commercial whaling makes difficult to disentangle the drivers of the spatial and temporal distributions, these data have been used in the past as proxy for the location of major ocean features, such as the sea-ice edge. We propose here a use of these data to assess various macroscopic features of climate model results from the suite of the Climate Model Intercomparison Project phase 6 (CMIP6) during the historical simulation period (1920-1970). We have focused on humpback whales, due to their particular environmental niche and for being the species targeted the most at the beginning of the century. This species is usually found in open waters adjacent to the sea ice edge, and can therefore provide an optimal proxy for oceanic conditions. The results using 22 CMIP6 models indicate that the model median overestimate the extent of summer Antarctic sea ice. In the majority of models, the historical sea-ice edge is simulated northward of the typical regions in which humpback whales were caught. This is an indication that the tuning and assessment of sea ice models using satellite-era observations may lead to an overshooting of Antarctic ice extent earlier in the century.

SCAR 2020

Antarctic Science - Global Connections

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SESSION 6

PAST CLIMATE VARIABILITY FROM ANTARCTICA AND THE SOUTHERN OCEAN

Liz Thomas
Tessa Vance, Krystyna Saunders, Dieter Tetzner

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Southern Ocean Sea Surface Temperature Response to Millennial-Scale Climate Change During Marine Isotope Stage 3: A Compilation.

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The temporal and spatial response of the Southern Ocean (SO) to rapid climate changes during Marine Isotope Stage 3 (MIS-3) is poorly constrained. Here we present a compilation of previously published high-resolution sea surface temperature (SST) records from 30°S to 60°S. We synchronise all records to the Antarctic Ice Core Chronology (AICC2012) and determine the presence and magnitude of warming corresponding to Antarctic Isotope Maximum (AIM) events. The individual SO sediment cores record warming events during 50% to 100% of all Antarctic Isotope Maxima events. The Atlantic sector of the SO has on average +0.59°C larger SST anomalies than the Pacific sector during warming events. The Atlantic sector also records more of the events in the individual core records (75% compared with 60%). Furthermore, the median amplitude of SO SST increases are positively correlated to the duration of Greenland Stadial periods ($r^2 = 0.94$, $n = 9$, $p < 0.0001$). This correlation solidifies the linkage between northern high latitude climate variability, AIM events and Southern Ocean SST variability during MIS-3. This compilation of records provides the first timescale-consistent look at the response of the SO to the rapid climate changes of MIS-3, and is consistent with the thermal see-saw theory of a heat reservoir in the South Atlantic propagating around the Southern Ocean.

1712

Understanding rapid changes in Antarctic sea ice extent using large climate model ensembles

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Antarctic sea ice extent underwent a rapid decline in the spring of 2016 and has remained below climatological averages since. Recent studies suggested that enhanced tropical convection in the Indian Ocean and Maritime Continent contributed to the highly anomalous wind patterns that led to the initial decline, with tropical-extratropical interactions also implicated in its sustained maintenance. Here we utilize the Community Earth System Model 40-member large ensemble simulations to explore the ability for rapid increases and decreases in Antarctic sea-ice extent over the historical past in various seasons. We find instances of similar multi-year decreases in the model and explore the mechanisms by which these occurred. The impact of the tropics in the determining the phase of rapid changes in sea ice is also analysed using pacemaker simulations.

1654

Cross-signal analysis of the Drake Passage flow and the Agulhas Leakage during the last deglaciation

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The Agulhas Leakage may apply a considerable influence on the interocean fluxes of heat and salt strength and stability of the Atlantic Meridional Overturning Circulation (AMOC). With the current geographical configuration of the Southern Ocean, the water gates of Drake Passage and Agulhas Current are critical points for the so-called “Cold and Warm Water Routes” and for the entry of intermediate water masses in the Atlantic, which contribute to the surface return flow that balances the export of deep waters from the North Atlantic. We present an analysis of the synchronicity of millennially-resolved signals from the Drake Passage and the Agulhas current during the last 25,000 years using the cross wavelet analysis, quantifying the signal strenght and time lag of these two gateways. Results show that the anti-phase signal from sea surface temperatures in the Drake Passage are well correlated with the significant increasing of the Agulhas Leakage, suggesting a wider Southern Hemisphere response signal on the salinity anomalies. Using global sea level data and orbital variability as suplemental information for the cross-wavelet analysis confirmed that Agulhas leakage increasing intensity is related to minima in precession, sinchronized with changes in the Drake Passage flow. These connections are important for the operational mode of the Atlantic Meridional Overturning Circulation (AMOC).

1211

X-Radiographic Images of Core Sediments from Grand Lagoon at Bulgarian Antarctica Base, Livingston Island-South Shetland Islands, West Antarctica.

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This study presents to research the depositional patterns inferred from X-radiographic images of core sediments from Grand Lagoon at Bulgarian Antarctic Base “St. Kliment Ohridski” where is located in between coordinates S 62º38'28.01" and W 60º21'53.88", is also situated at South Bay of Livingston Island.

For the realization of this research will be applied to the study of sedimentological and geochemical characteristics in modern glaciogenic sediments collected from the Grand Lagoon.

So, 10 core samples with depths range from app.20 to 50 cm collected at each sites located approximately 50 m apart from the water and ice-free area along the Grand Lagoon for pioneer investigations during the 2018 Antarctic austral summer. Core sediment samples were taken with Plexiglas acrylic tubes and kept to analyze at laboratory. X-ray radiography was directly performed on core samples without any processing. The geochemical and sedimentological analyses have also already going on and then furthermore the getting results will be interpreted and figured out as soon.

Some depositional layers with laminations also were detected by X-ray radiography. These laminated layers with inferred from radiographic images of core samples will probably indicated that glaciogenic sediments deposited under different seasonal conditions at depositional site area where is dark grey to black, moist to wet, mostly sandy and mixed with small clayey aggregates observed in preliminary field studies.

As a result, the area is thought to be directly affected by under the coastal beach dynamics, fluvioglacial erosional and depositional processes during the seasonal weathering changes at surrounded area.

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Climatic information archived in ice cores: impact of intermittency and diffusion on the recorded isotopic signal in Antarctica

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The isotopic signal ($\delta^{18}O$ and δD) imprinted in ice cores from Antarctica is not solely generated by the temperature sensitivity of the isotopic composition of precipitation but also contains the signature of the intermittency of precipitation patterns as well as of post-deposition processes occurring at the surface and in the firn. This leads to a proxy signal recorded by the ice cores that may not be representative of the local climatic variations. Due to precipitation intermittency, the ice cores only record brief snapshots of the climatic conditions, resulting in aliasing of the climatic signal, and thus a large amount of noise which reduces the minimum temporal resolution at which a meaningful signal can be retrieved. The analyses are further complicated by isotopic diffusion which acts as a low pass filter that dampens any high frequency changes. Here, we use reanalysis data (ERA-Interim) combined with satellite products of accumulation to evaluate the spatial distribution of the transfer function that describes the formation of the isotopic signal across Antarctica. The minimum time scales at which the signal-to-noise ratio exceeds unity range from less than a year at the coast to a thousand years further inland. Based on solely physical processes, we were thus able to define a lower bound for the time scales at which climate variability can be reconstructed from ice core water isotopic compositions.

621

Comparing the strength of the link between surface mass balance and temperature in ice cores and models in Antarctica over the last centuries

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Historical climate model simulations must be evaluated against measured records of surface mass balance (SMB) to assess the robustness of modeled future SMB. Here, we compare the strength of the link between SMB and surface air temperature (SAT) in modeled and measured data sets over the last century. We use several global climate models and the RACMO2.3 regional climate model (Van Wessem et al. 2018). Modeled results are compared to PAGES 2k ice-core compilations: Thomas et al (2017) SMB, Stenni et al (2017) d18O as a proxy for SAT, both for the last 150yrs, and the Nicolas and Bromwich (2014) SAT reconstruction, available only for the last 50yrs.
We show that the modeled SMB-SAT relationship is strong and positive at the regional scale (down to 5.5km with RACMO2.3), while the ice-core SMB-SAT or SMB-d18O relationship is weaker, over the last 150yrs.
To resolve the discrepancy between measured and modeled signals, we show that averaging ice-core records in close spatial proximity increases the obtained SMB-SAT correlation slightly, but not enough to match that obtained from the models. On the model side, the RACMO2.3 simulations allow us to highlight areas where SMB and SAT are weakly correlated. We show that wind-induced processes active locally can overwhelm the large-scale positive SMB-SAT relationship in these areas. The 5.5km RACMO2.3 output along Princess Ragnhild Coast shows that wind-induced snow redistribution affects each ice promontory. However, we show that the areas with a weak SMB-SAT correlation cannot explain the whole ice-core-model discrepancy in SMB-SAT correlation strength.

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Orbital-scale, glacial evolution of the Transantarctic Mountains during the Miocene Climatic Optimum and its termination (~15.5-13.8 Ma)

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An approximately ~50m thick sequence of well-dated ice-cemented sedimentary drill cores were recovered from the Friis Hills, McMurdo Dry Valleys in 2016. The cores provide new insights into the variability and extent of glaciation through the Transantarctic Mountains (TAM) during the Early to Mid-Miocene between 15.5-13.8Ma. This interval was characterised by a period of warmth within the Miocene Climatic Optimum (MCO; ~17-15Ma), when global average temperature 3-4°C warmer than today and atmospheric CO_2 levels up to 600ppm - one of the warmest intervals since the onset of Antarctic glaciation. The MCO was terminated by major global cooling and Antarctic wide ice-sheet expansion across the Miocene Climate Transition (MCT; ~13.8Ma). We document the evolution and orbital-scale glacial variability during this long-term transition in climate state.

Sediments deposited between ~15.5 -14.4Ma consist of alternating sequences of traction tills and moraines deposited during advances of a temperate alpine glacier system, and intervening fluvio-lacustrine sediments deposited during interglacial retreat, at a likely paleo-elevation of around 1000m, indicating a much warmer and wetter environment in the TAM than today. After 14.4Ma, till facies in the Friis Hills cores become progressively thicker, less muddy, more pervasively deformed and are punctuated by thinner intervals of organic rich fluvial/lacustrine interglacial sediments, but display similar facies to the underlying organic-rich interglacials. This suggests that glaciation became progressively colder, drier and more regionally-extensive during glacial periods heading into the MCT. However, interglacials remained warm enough to sustain tundra-style vegetation including Nothofagus at high elevations where mean summer temperature was 6-7°C.

1575

Paleooceanographic reconstruciton of the Southern Ocean based on coccolith assemblages.

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Southern Ocean (SO) plays an important role in regulating global climate. The diverse species (foraminifera, Coccolithophore and diatoms) in this study area respond to the hydrographic changes along with the movement of fronts. In this study, we reconstruct SO paleoceanography from coccolithohore abundance and assemblage variation using a radiocarbon dated (up to 42 ka BP) sediment core (SK200/22a) retrieved from north of Del Cano Rise of SO. The most abundant species were Emiliania huxleyi and Calcidiscus leptoporus along with Helicosphaera carteri, Gephyrocapsa oceanica, Gephyrocapsa muellerae, Gephyrocapsa sp., Gephyrocapsa sp. small, Reticulofenestra sp., Coccolithus pelagicus, Umbilicosphera sibogae and Florisphera profunda. The coccolith assemblage exhibits higher abundance during Holocene (5.78 X 109 coccoliths g-1 sediment) while it is lesser (0.92 X 109 coccoliths g-1sediment) during glacial stage. Interestingly, during the LGM the warmer species exhibit higher values than that of glacial values suggesting a localized warming event associated with increased availability of nutrients. C pelagicus, a cold water mesotropic species records higher values during LGM as compared to the Holocene indicating higher availability of nutrients. The warmer species exhibits lowered values during the glacial stage suggesting northward shift of Antarctic Polar Front and Sub-Antarctic Front. This is the first coccolith record from the Indian sector of Southern Ocean to understand the frontal variation and the past-climate changes in this region along with other microfossil records.

1560

Characterising surface and sub-surface marine heatwaves in the Kerguelen Plateau region

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The Kerguelen Plateau (KP) is home to a significant Patagonian toothfish fishery as well as being home to significant populations of seals, seabirds and whales. These populations are supported by the increased primary production that is consistently observed in the eddy-field caused by the interruption of the ACC as it moves around the plateau.

Using a combination of observations provided by tagged elephant seals and model output from a data-assimilating high-resolution ocean model we characterise the frequency and intensity of marine heatwaves that have occurred in the KP region between 1994 and 2016. We show that anomalously warm water can penetrate from the surface to a depth of at least 150m and that depth penetration of warm water is likely related to downwelling favourable winds. Similarly, upwelling favourable winds appear to be related to the dissipation of marine heatwaves in the region.

We also show that the ocean temperature at both the surface and at 150m on the KP is significantly correlated with key modes of climate variability with regions of the KP displaying significant correlations with the Indian Ocean Dipole, El Nino Southern Oscillation and the Southern Annular Mode. These results suggest there may be potential predictability in ocean temperatures, and their extremes, in the KP region.

Strong MHWs, as have been seen in recent years, may be detrimental to the unique ecosystem of this region, including economically relevant species, such as the Patagonian Toothfish.

1031

El Niño Southern Oscillation and Southern Annular Mode signals from sea salt deposition in the Mount Brown South ice core, East Antarctica

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The mid-latitudes of the Southern Ocean are among the stormiest on Earth, yet the longer-term variability in atmospheric circulation in this region remains poorly understood. This is particularly true for the southern sector of the Indian Ocean, where reliable observations are primarily limited to the satellite era as few habitable land-masses means observational station data is sparse. Model studies and paleoclimate records (ice-cores and corals) suggest decadal variability in atmospheric circulation exists in this region, however, long annually resolved ice-core records are needed to further investigate these processes. Until recently, the Law Dome Summit South (DSS, 66.769°S, 112.806°E), remained one of few multi-century annually resolved ice-core records in East Antarctica. A new ice-core drilled at Mount Brown South (MBS, 69.111°S, 86.312°E) approximately 1000km west of DSS provides an additional high-resolution record at millennial timescale. We present a comparison between the sea salt concentrations for DSS and MBS over the satellite era. Our results suggest that annual sea salt deposition at MBS contains significant signals for the El Niño Southern Oscillation (ENSO) and the Southern Annular Mode (SAM). These signals are further demonstrated by composite maps that show (a) significantly higher (lower) sea surface temperature anomalies in the western equatorial Pacific during high (low) sea salt years that correspond with El Niño events (La Niña events), and (b) a significant contraction (expansion) of zonal wind anomalies during low (high) sea salt years that correspond with the positive (negative) SAM phase.

A Preliminary Reconstruction of Miocene Ocean-Climate History of the Ross Sea, Antarctica based on Foraminifera from IODP Site U1521 and DSDP Site 272

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The International Ocean Discovery Program (IODP) Expedition 374 recovered deep-sea sediment cores from the continental shelf of the Ross Sea, Antarctica to evaluate the stability of the Antarctic Ice Sheet (AIS) during the warmer-than-present climates of the Miocene. Studies of AIS stability are critical to understand the modern impacts of anthropogenic warming on the Ross Sea sector, as numerical modeling indicates that this region is highly sensitive to changes in ocean and atmospheric heat flux. Located in the Pennell Basin, IODP Site U1521 recovered sediments of the Miocene Climatic Optimum (MCO; 17-14.5 Ma) and Middle Miocene Climatic Transition (MMCT; 14.2-13.8 Ma). Global proxy records indicate dynamic changes in carbon cycling, prolonged global warmth, and reduced ice cover during the MCO, followed by ice expansion during the MMCT. To reconstruct changes in the Ross Sea and the associated marine paleoenvironments during the Miocene, assemblages of fossil benthic and planktic foraminifera were analyzed from Site U1521 and assessed with foraminiferal data from DSDP Site 272.
Prior to the MCO, low diversity and a mix of in-situ and reworked foraminifera, coupled with lithology, indicate periodic ice advance and retreat. During the MCO, an increase in species diversity and predominantly in-situ microfossils suggests an interval of highly productive open water and warmer sea surface temperatures. A widespread hiatus across the shelf implies grounded ice during the late stages of the MCO. A decrease in diversity and preservation suggests a shift to a less productive paleoenvironment during the MMCT.

1088

Influence of climate modes and solar variability on East Antarctic ice core temperature during the past two centuries

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El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillations (PDO) and their interactions with Southern Annular Mode (SAM) largely influence Antarctic climate. Solar variability is also known to contribute Antarctic climate variability. However, the relative roles of these climate modes and solar variability are not yet well understood particularly in the backdrop of global warming scenario. In this study, we have reconstructed high resolution temperature of the past two centuries (1809 – 2013 CE) based on oxygen isotope (δ18O) record of a new ice core (IND-33/B8) from Dronning Maud Land (DML), East Antarctica together with other published records. Our δ18O record broadly agree with the simulation result from water isotope-enabled ECHAM5-wiso model except for the periods of large excursions observed in the ice record. We found that ~32% variability in δ18O records of the DML region is attributed to temperature, which is modulated by ENSO and PDO, whereas 27% variability is related to moisture source changes and transport processes. Further, moisture sources and its transport are primarily controlled by wind and the sea ice variability modulated by the Southern Annular Mode (SAM) at annual to sub-decadal time scale, whereas solar variability influences at decadal scale (9 -12 yrs band). DML temperature record shows dominant ENSO signal during the time slices 1825-1835, 1950-1960 and 1975-1995 CE with a dramatic shift from low (9-16 yrs) to high (2-8 yrs) frequency bands since 1940s. We observed significant correlation ($r=0.42$, $p<0.05$) between SAM and temperature during 1965-1993 CE when SAM started shifting to positive phase.

1577

Quantifying Changes in Atmospheric Oxidative Capacity since 1870 AD Using Measurements of 14CO in ice and firn from Law Dome, Antarctica

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Climate change and stratospheric ozone depletion are affected by the emissions of key trace gases as well as by their loss from the atmosphere. Hydroxyl, OH, is the main tropospheric oxidant and determines the atmospheric lifetime of many greenhouse gases and ozone depleting gases. Changes in OH concentration ([OH]) in response to large changes in reactive trace gas emissions are uncertain and constraints on future simulations by atmospheric models come from limited observations. Reconstructions of 14CO from ice cores could in principle provide such constraints but are complicated by in-situ cosmic ray production of 14CO. Recent work in Antarctica and Greenland shows that this in-situ component would be relatively small and accurately quantified at sites with very high snow accumulation rates. A joint US-Australian program in 2018-19 measured air in firn and ice at Law Dome, Antarctica (DE08-OH, 1.2 m a-1 ice). Trapped air was extracted using an on-site large-volume (~500 kg) ice melting system. Ice core air sample ages spanned from the 1870s to the early 2000s and the firn-air samples spanned from the early 2000s to present. Analyses of [CO] and halocarbons in the samples show a relatively low and stable procedural CO blank and demonstrate that the samples are unaffected by ambient air inclusion. 14CO measurements in these firn and ice core air samples will be presented. This 14CO history will be interpreted with the aid of the GEOS-Chem chemistry-transport model to place the first long term observational constraints on the variability of Southern Hemisphere [OH].

1623

ICEPRO: An International Collaboration Effort for improving Paleoclimate Research in the Southern Ocean

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The Southern Ocean (SO) is an active regulator of global climate through its influence on the modulation of the global ocean circulation, the phytoplankton productivity as well as nutrient cycles, the transfer of energy and gas between the ocean and the atmosphere, and sea level. Despite its importance, seasonal and sparse distribution of instrumental data across the SO prevent a robust assessment of the physical and biological response and feedback on future climate change. Paleoclimate data are therefore essential to document the natural variability of environmental conditions and identify their drivers from decadal-to-millennial timescales. However, in paleoclimate studies, several questions remain unaddressed due to the lack of robust proxy calibration. While some tools are better constrained than others, the mechanisms controlling them are not fully understood. A critical step to improve their use is to conduct a systematic multi-annual collection of samples and data throughout the SO. ICEPRO has been initiated to strengthen existing collaborations and creating new connections among several partners regularly crossing through different transects the SO and who have the opportunity to sample the water column and marine sediments spanning at least the last 2,000 years. Such collaborative work could therefore cover most of the important regions of the SO, thus allowing a better monitoring of modern environmental and hydrological conditions, and ultimately improve calibration of tools commonly used for paleoreconstructions. Here we aim to present ICEPRO, its first steps and results we obtained from the last Antarctic cruises as well as our future ambitions.

1379

Mid-to-Late Holocene climatic oscillations at northern Antarctic Peninsula from combined lacustrine and glacial records

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Meteorological data and climate models have pointed the Antarctic Peninsula as one of the most rapidly warming regions of the planet. However, recovering the past climate changes at that site using ice cores is still challenging since summer meltings effect ice core glacio-chemistry. In this scenario, the sediment core profiles retrieved from Holocene pro-glacial lakes arise as promising for reconstructions. The sediment cores analysis presented here comprise data from an isolated lake, covering the mid-to-late Holocene, and 9 (nine) cores surveyed from lakes located at the end of braided glaciers meltwater streams covering the modern epoch (last 150 years). From this approach, we were able to ensemble the sedimentary record and produce an integrated sedimentation history that allowed comparison with ice core records of WAIS, especially from northern Antarctic Peninsula, the James Ross ice core. Sediment core dated from the Holocene presented regular marked laminations indicating pronounced 80-to-100 yr periodicities revealing a possible signal of the Gleissberg solar cycle. Main finding from this work is an identification of a prolonged cooling phase observed during the last 2kyr. We propose here that such event is related to the combined impact of the regional volcanism concomitant to a reduced solar irradiance based on latest reconstructed time series. This work is part of UN/FAO/IAEA climate change program with support of the Brazilian and Russian Antarctic Programs.

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Southern Hemisphere Pressure Relationships during the 20th Century: Implications for Climate Reconstructions and Model Evaluation

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The relationship between Southern Hemisphere middle and high-latitude regions has made it possible to generate observationally-based Antarctic pressure reconstructions throughout the 20th century, even though routinely collected observations for this continent only began around 1957. Nearly all reconstructions inherently assume stability in these relationships through time, and in the absence of direct observations, this stationarity constraint can be fully tested in a model setting. Seasonal pressure reconstructions based on the principal component regression (PCR) method spanning 1905 – 2013 are done entirely within the framework of the Community Atmospheric version 5 (CAM5) model in this study in order to evaluate this assumption, test the robustness of the PCR procedure for Antarctic pressure reconstructions, and to evaluate the CAM5 model. Notably, the CAM5 reconstructions outperformed the observationally-based reconstruction in every season except the austral summer. Other tests indicate that relationships between Antarctic pressure and pressure across the Southern Hemisphere remain stable throughout the 20th century in CAM5. In contrast, 20th century reanalyses all display marked changes in mid-to-high latitude pressure relationships in the early 20th century. Overall, comparisons indicate both the CAM5 model and the pressure reconstructions evaluated here are reliable estimates of Antarctic pressure throughout the 20th century, with the largest differences between the two resulting from differences in the underlying reconstruction predictor networks and not from changes in the model experiments.

1525

Past Sea Surface Temperature and Sea Ice Extent and their role in Fragilariopsis kerguelensis size variation from the Southern Ocean”

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The present study aims in addressing the past changes in the Southern Ocean (SO) system in a quantitative and process oriented way in order to improve the understanding of future climate and environment. In this study we have reconstructed the summer sea surface temperature (SST) and winter sea ice presence (SIP) along with diatom morphometry from the sediment core located at 55˚01’ S, 45˚09’E from the Indian Sector of SO. The maximum SIP of 1-2 months/year and lowest SST of 1-3°C were recorded during glacial stages, this probably resulted in reduced valve size (~250 microns) of Fragilariopsis kerguelensis. Comparison of our records with published studies demonstrates that during the glacial stages SIP was of longer duration in the Atlantic and western Pacific Sector than in the Indian Sector. This suggests additional dynamical processes in the Atlantic and Western Pacific Sector, whereby sea-ice transport by the Weddell and Ross Gyre may have allowed WSI further to the north. The relatively lower SIP in the Indian Sector resulted in the largest mean F. kerguelensis sizes which was facilitated by the efficient utilization of the nutrients by these diatoms. This study suggests that changes in the past sea ice dynamics may control the sizes more rapidly in the Atlantic and Western Sector than anywhere else in the SO if the Weddell and Ross Gyre weakens in the coming decades.

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A multi-proxy reconstruction of the SAM in the Southern Ocean Sector during the Holocene and Last Interglacial

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Of paramount interest to reconstructing Antarctic regional paleoclimate are: (i) the zonal vacillations of the Southern Hemisphere westerlies, and their encapsulation within the Southern Annular Mode (SAM) of variability; (ii) the atmospheric Planetary Waves controlled by orography and land/sea contrasts in diabatic heating; and (iii) the geographic distribution of tropical-Antarctic teleconnections.

The approach presented in this talk is based around reconstructing 'macroweather', the centennial-scale upscaling of weather patterns and climate modes. Past macroweather and climate shifts can be resolved on a deterministic manner on sub-orbital time scales due to the coupling between macroweather and the latitudinal temperature gradient. Advances in data-model assimilation using hemispheric to regional multi-proxy data are presented for the last millennium, early, middle and late Holocene and the Last Interglacial (MIS Stage 5). An alternative approach is to project far field proxy climate and sea-level data onto Antarctica to develop an 'inverse' view of climate influences by developing: (i) regional ice-sheet basin meltwater fingerprints from far field sea-level records, and, (ii) circumpolar wind fields from far field paleoclimate proxies and ice cores.

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Influence of ice-ocean interactions in the Southern Ocean on Antarctic temperatures and on the global carbon cycle over the past millennia.

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Reconstructions of Antarctic surface temperature covering the past millennia display a large centennial variability that is not synchronous with fluctuations recorded on other continents and which is generally not well simulated by models. Many processes can be at the origin of these temperature variations such as teleconnections with tropical oceans and changes in the Southern Ocean. The focus here will be on the latter, in particular on ice-ocean interactions that regionally control the stratification of the Southern Ocean and thus have a large impact on the exchanges of heat and carbon between the ocean and atmosphere. Changes in the Southern Ocean circulation and stratification also influence the carbon cycle at global scale. It is generally suggested that atmospheric CO2 variations over the past two millennia were mainly controlled by land processes but the Southern Ocean might also have played a role. We will thus test whether the joint analysis of Antarctic temperature and atmospheric CO2 concentration fluctuations can inform us on the origin of the observed changes over this period. In this purpose, we use the climate model LOVECLIM which includes a representation of the global carbon cycle. Experiments over the last two millennia will address the sensitivity to realistic perturbations of the wind stress and freshwater forcing from the ice sheet. Finally, experiments with data assimilation will allow assessing what constraints are needed for model results to better reproduce the reconstructed temperature history.

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Can we reconstruct the formation of large open ocean polynyas in the Southern Ocean using ice core records?

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Large open-ocean polynyas, defined as ice-free areas within the sea ice pack, have been observed only rarely over the past decades in the Southern Ocean. In addition to smaller recent events, an impressive sequence occurred in the Weddell Sea in 1974, 1975 and 1976 with openings of more than 300,000 km2 that lasted the full winter. Those big events have a huge impact on sea ice cover, deep-water formation and more generally on the Southern Ocean and the Antarctic climate. However, we have no estimate of the frequency of the occurrence of such large open-ocean polynyas before the 1970s. Their overall role in the natural climate variability at high southern latitudes is thus unknown. No paleoceanographic data is available in the Weddell Sea to reconstruct directly past polynya activity. Our goal here is to test if this could be done using continental records, and specifically, observations derived from ice cores. The fingerprint of big open-ocean polynyas is first described in reconstructions based on data from weather stations and ice cores for the 1970s and in climate models. It shows a clear signal, characterized by a surface air warming and increased precipitation in coastal regions adjacent to the eastern part of the Weddell Sea where several high-resolution ice cores have been collected. The potential to base reconstructions of polynya activity over past centuries on this signal using simple statistical techniques as well as data assimilation is explored.

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A constrained optimization (CONOP) biostratigraphic framework for Antarctic unconformities during the Cenozoic

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The quantitative biostratigraphic method of Constrained Optimization (CONOP) provides a common framework including geochronology for the correlation of Antarctic sediment cores to overcome discontinuous records and facies constrained biostratigraphy. CONOP has been used previously to improve age models of Antarctic shelf sites (i.e. ANDRILL-1B; Cody et al., 2012) and analyse phytoplankton turnover in response to climate cooling over the last 15 million years (Crampton et al., 2016).

The Southern Ocean biostratigraphic database now incorporates taxon ranges for diatom, radiolaria, foraminifera and nannofossils spanning the Late Cretaceous to present, with 6 radiometric ages and 342 individual paleomagnetic reversals for 50 sites south of the Polar Front. This project intends to extend beyond the Polar Front to investigate biogeographic effects at taxon and species levels. The CONOP method of computerised graphic correlation and parsimonious sequencing, allows objective assessment of assigned paleomagnetic reversals and the uncertainty of correlation to be ascribed.

This work focuses on the geographical distribution of changes in sedimentation rates in relation to widespread unconformities, and developing on seismic interpretations (e.g. DeSantis et al., 2003; Brancolini and Leitchenkov, 2010; Escutia et al., 2011; Gohl et al., 2013). Results will ultimately help inform and refine biostratigrahpic age models from the recent phase of IODP drilling around the Antarctic margin. The current development of astroCONOP (Meyers, pers. comms) will also be discussed here in the context of further chronological refinement and assistance with correlation of traditional Antarctic proxies and timeseries to those preferentially used in more temperate climates (i.e. δ18O).

1405

2000 Years of Variability in the Southern Annular Mode (SAM) from Tree Rings and Ice

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The Southern Annular Mode (SAM) is the leading mode of climate variability in the middle to high latitudes of the Southern Hemisphere, where it affects the strength and position of the westerly winds, precipitation, and temperature anomalies across oceans and continents. While several reconstructions of the SAM have been developed from existing proxies there is little agreement among them prior to the mid 1800s. Further, existing SAM reconstructions are focused on the Pacific Ocean sector, with less data from the Indian Ocean sector passing proxy screening tests. Here, we describe a project that will combine tree-ring data from Tasmania, Australia with two high-resolution East Antarctic ice cores (Law Dome and Mount Brown) to reconstruct the behavior of the SAM over the last 2000 years in the Indian Ocean sector. This new SAM record will be compared with last millennium climate model simulations in order to identify internal and external forcing of decadal to centennial variability in the SAM. As a precursor to data assimilation, we evaluated the features of the SAM in several GCMs and identified optimal sensor locations in different models to examine how they compare with available proxy sites. Initial results indicate that many GCMs exaggerate the annular shape of the Southern Annular Mode relative to reanalysis data (CSIRO, FGOALS, IPSL, MIROC, and MRI) while others more closely match (CESM, MPI and HadCM3). Data processing of the tree ring and ice core proxies is currently underway.

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Sediment accumulation rates at the edge of the Atlantic: relationships among sea ice, water current and sea floor relief.

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Sediment accumulation rates were studied at the southernmost Atlantic Ocean in the vicinities of the Filchner Trough. This is an important region for water mass formation and a marine mammal feeding spot, presumably following high primary production. The region also experiences contrasting sea ice patterns. In spring and summer there are open water conditions at the east of the trough, whereas at the west, the sea surface usually remains covered by multiyear sea ice. Earlier studies showed that sedimentary organic carbon and biogenic silica were more concentrated on the eastern flank of the trough. We attempted to study whether sediment accumulation follow this pattern and its implication for the long-term (hundreds of years) carbon storage in the sediment column. We analyzed 16, 20-cm sediment cores along the axis of the Filchner Trough and the adjacent continental shelf and slope. Sediment accumulation rates (SAR) varied from 8 to 128 cm ky-1. The highest SAR were found on the deepest parts of the axis of the trough and the shelf and slope of its eastern flank, whereas the smallest SAR were found in the shelf and slope of the western flank and at the mouth of the trough. Preliminarily, SAR values matched with the sea-ice pattern and the water current system, showing high values in areas with seasonal open water conditions and the inflow of deep water onto the shelf and low values in areas where multiyear sea ice persists and the outflow of dense cold water towards the deep Weddell Sea.

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Climatology of Antarctic ozone zonal asymmetry by MERRA-2 data

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Antarctic ozone climatology was calculated over the 1980–2018 period using monthly mean data from MERRA-2 reanalysis. The 2D (total ozone column) and 3D (ozone concentration) mean ozone values climatology for zonal band (90°S–0°S) at 42 pressure levels (1000–0.1 hPa) were retrieved. The amplitude of ozone zonal asymmetry was calculated. The monthly, latitude, and longitude morphology altitude analysis have been made. The maximal ozone zonal asymmetry is observed in spring, especially in October with dominant wave-1 zonal minimum at 0°–90°W and maximum at 120°E–180°E. The area of high ozone content is located in zonal band (40°S–80°S) with gradual shift to the pole from September to November. Latitudinal mean maximum in zonal mean ozone distribution is observed near 62°S in September, 66°S in October, and 68°S in November. Poleward shift of latitude ozone maximum continues until March with decreasing of ozone level, but in April the shift reverses into equatorward. Eastward shift of longitude ozone zonal maximum from month to month could be observed in ozone distribution from September (144°E) to October (166°E), and westward from October to November (156°E) but for ozone zonal minimum there is only eastward shift from September (29°W) to November (6°W). The highest difference in altitude ozone distribution is observed during October in the stratosphere between ozone zonal minimum (66°S, 30°W, 30hPa) and maximum (66°S, 160°E, 40hPa) points. The difference reaches approximately 4x10–12 cm–3, which is about 66% of the zonal average value at this level.

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The seasonal signal and variability of 17Oexcess in two contrasting ice cores from coastal Antarctica

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Stable water isotopic ratios are routinely measured in ice cores to help constrain past climate variability. In addition to measurements of the traditional water isotopic ratios,
δD and δ18O, the secondary parameters, dexcess and ^{17}Oexcess, provide insight into variability in the oceanic evaporative region. Ice core ^{17}Oexcess is thought to be primarily controlled by variations in relative humidity in the source region and has the potential to be a more reliable recorder of source conditions than dexcess, however questions still remain about how ^{17}Oexcess responds to climatic variability and fractionation along the transport pathway. We present ^{17}Oexcess data for the past 40 years from two contrasting ice core locations; James Ross Island on the Antarctic Peninsula, and Mount Brown South in East Antarctica. Both ice cores are situated in high-accumulation coastal sites, and we present ^{17}Oexcess measurements at seasonal resolution spanning the satellite observation period. The relationship between ^{17}Oexcess in the ice cores and variability in relative humidity and temperature in the source region, transport pathways, and temperature at the deposition site are investigated. This detailed analysis allows us to assess the impact of these climate variables on the preserved ^{17}Oexcess signal in the two ice cores, and the potential for developing longer ^{17}Oexcess-dervied reconstructions from these sites.

1143

Rates of dust transport to Macquarie Island during the mid to late Holocene: Implications for the position and strength of the mid-latitude westerlies and ecosystem fertilisation

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Due to its location within the core region of the Southern Hemisphere mid-latitude westerlies, Macquarie Island winds arrive almost exclusively from the west-northwest. Thus, under certain conditions, air masses arriving with enhanced or reduced dust input through time are likely associated with a reduction in the strength and/or the position of the mid-latitude westerlies, (possibly associated with more positive SAM-type conditions) and increased advection of heat to the atmosphere of the Southern Ocean. At the same time, dust is known to play an important role in ecosystem productivity, with phytoplankton production in the HNLC Southern Ocean linked to dust fertilisation. In addition, dust may also play an important role in ecosystem production on Macquarie Island itself.
In this study, we examine dust transport to Macquarie Island in the mid to late Holocene by analysing three peat cores collected from Macquarie Island in 2018. Geochronology is established for each of the cores with 210Pb and 14C dating, and they are analysed for minerogenic input (dust). Ecosystem response is quantified with diatoms, pollens, C/N ratio, and N-alkanes. Through associations between ecosystem variation and mineral input, we draw insights into biotic processes in the high-latitudes and the adaptive capabilities of the food web. Our results imply episodes of increased dust transport, possibly pointing to reduced strength of the westerly winds at these times. The results also imply increased ocean fertilisation and associated phytoplankton response at these times, which is likely to be associated with enhanced CO2 drawdown.

1133

Environmental Controls on Laminae Frequency and Biological Productivity in Adélie Land

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Wind driven currents along Antarctica's coastal margins regulate water mass exchange between the Antarctic continental shelf and Southern Ocean. As such, these currents exert control on the delivery of heat, salt, and nutrients to the coastal margins and marine based ice sheets. This exchange affects sea ice extent, primary productivity, and bottom water formation, and may be capable of change at centennial to millennial timescales. However, characterising the long-term climate variability of wind driven currents, and the effect on primary productivity, is difficult due to sparse and temporally limited observational data. Here, we present a new Holocene climate record from Integrated Ocean Drilling Program (IODP) sediment core U1357B in the Adélie Basin, East Antarctica. The sediment core consists of contrasting light and dark centimetre scale laminations through the entire 170 m of core, with light laminations reflecting changes in biological sedimentation. Using X-Ray Computed Tomography, and supported by grain size distributions, XRF data, and other physical core properties, we developed a record of near annual biogenic bloom events and link these bloom events to changing environmental conditions. As primary productivity in many parts of the Antarctica's coastal regions is strongly linked to wind-driven upwelling processes, we investigate how variations in grain size can be used to assess changes in wind-driven currents, which may influence dark and light laminae characteristics through the Holocene. The result is a centennially resolved coastal current reconstruction for the Holocene along the Adélie Land Margin.

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Seasonal Climate Variability in West Antarctica During the Holocene

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Paleoclimate proxies of the annual cycle are difficult to obtain and require a confluence of specialized technology, methodology, and modeling to interpret. This represents one of the great challenges of paleoclimate studies. In the case of ice core science, the ability to measure and interpret the annual cycle has recently become possible for water isotope records. Here, we discuss results from the West Antarctic Ice Sheet (WAIS) Divide ice core during the Holocene, including: 1) A continuous reconstruction of the annual signal throughout the Holocene, and 2) Corrections for differential diffusion due to the seasonality of accumulation. We use modeling (HadCM3) to explain changes in the summer and winter extrema, as well as the annual amplitude through time. We also discuss where modeling deficiencies exist. As additional high-resolution ice core records become available (e.g. Renland, EGRIP, Hercules Dome, possibly GISP, etc.), the ability to analyze and interpret changes in the annual cycle across space and time will improve. As a result, our understanding of climate change on timescales that humans most relate to - variability from one year to the next - will also improve.

Reconstructing Southern Ocean sea surface temperatures from an East Antarctic ice core.

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The lack of reliable and long observational records of sea surface temperature (SST) from the Southern Ocean remains a key factor in limiting our attempts to understand climate variability on interannual to centennial scales in the Southern Hemisphere. The Law Dome DSS ice core from East Antarctica provides an annually resolved climate record, capturing atmospheric and ocean processes from the Pacific and Indian sectors of the Southern Ocean. We present a 1000 year reconstruction of sea surface temperature in the Southern Ocean using snow accumulation and sea salt records from the DSS ice core. Sea salt aerosols falling on Law Dome, carried by moisture sourced predominately from the Indian sector of the Southern Ocean, are found to be a proxy for SST through the relationship between atmospheric-ocean heat exchange and wind speed. Back trajectory analysis of ERA-Interim reanalysis data shows the origin of the moisture falling as snow on Law Dome to be predominately from the Indian Ocean sector of the Southern Ocean and reconstructs the seasonal cycle of sea salt concentrations with good agreement with the measured ice core record. Examination of the time series of the the dominant temporal modes of the SST reconstruction shows a break point in the time series at 1259CE. This shift is coincident with a series of volcanic eruptions also recorded in the same ice core archive, thus eliminating timing uncertainties between the two events, suggesting that the end of Medieval Climate Anomaly was a result of a climate response to the eruptions.

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Antarctic Surface Mass Balance: natural variability, noise and detecting new trends

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The emergence of new, statistically robust trends in Antarctic surface mass balance (SMB) requires an understanding of the underlying SMB variability (noise). We show that simple white or AR[1] noise models do not adequately represent the variability of SMB in both the RACMO2.3p2 SMB model output (1979-2017) and composite ice core records (1800-2010), under-estimating low-frequency variability. By testing a range of noise models, we find that a Generalized Gauss Markov (GGM) model better approximates the noise around a linear trend. The general preference for GGM noise applies over spatial scales from the total ice sheet down to individual drainage basins. Over the longest timescales considered, trend uncertainties are 1.3-2.3 times larger using a GGM model compared to using an AR1 model at the ice sheet scale. Overall, given our characterisation of noise, our results suggest that larger trends or longer periods are generally required before new SMB trends can be robustly separated from background noise.

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Temperate rainforests near the South Pole during peak Cretaceous warmth

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The mid-Cretaceous was one of the warmest intervals of the past 140 million years (Myr) driven by atmospheric CO2 levels around 1000 ppmv. In the near absence of proximal geological records from south of the Antarctic Circle, it remains disputed whether polar ice could exist under such environmental conditions. Here we present results from a unique sedimentary sequence recovered from the West Antarctic shelf. This by far southernmost Cretaceous record contains an intact ~3 m-long network of in-situ fossil roots. The roots are embedded in a mudstone matrix bearing diverse pollen and spores, indicative of a temperate lowland rainforest environment at a palaeolatitude of ~82°S during the Turonian–Santonian (92–83 Myr). A climate model simulation shows that the reconstructed temperate climate at this high latitude requires a combination of both atmospheric CO2 contents of 1120–1680 ppmv and a vegetated land surface without major Antarctic glaciation, highlighting the important cooling effect exerted by ice albedo in high-CO2 climate worlds.

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Mid-to-late Holocene climate variability in the Northern Antarctic Peninsula

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The Antarctic Peninsula (AP) is one of the most sensitive areas to the recent global warming. Over the last 50 years, AP has approximately lost around 75 % of its ice shelves. The main causes of this rapid ice shelf regression are still debated given that the surface atmosphere temperatures (SAT), the subsurface ocean temperatures (SOT), or both can predominantly drive to this fast decline. However, due to the lack of observations, it remains difficult to disentangle the main physical processes primarily acting on the ice shelves. Past records can provide such information. Nevertheless, while a series of SOT records spanning the last millennia around the Northern AP have been produced, only one Holocene ice-core SAT record has been generated, in James Ross Island, Eastern AP. There is therefore no detailed information on the SAT centennial evolution elsewhere around the AP. To fill this gap, we used a recently developed method based on the application of the Glycerol Dialkyl Glycerol Tetraether (GDGT) from sediments of the Limnopolar Lake (62º37'23S, 61º06'24W), Byers Peninsula, South of Livingston Island, in order to investigate the past secular SAT changes over the last 7,500 years in the Western AP. Those data will be then compared to previous reconstructions derived from marine sediment cores and ice cores around the AP. Results and discussion of this ongoing work will be presented for the first time during the OSC SCAR-2020.

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Southern Weather Discovery - citizen science data rescue of high latitude historic weather and environmental observations

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Understanding key modes of variability and southern high latitude trends presently relies on sparse data and limited palaeo proxy evidence. This situation can be improved by augmenting meteorological data coverage for the 19th and early 20th Centuries, which would bolster Southern Hemisphere weather reconstructions derived only from surface observations (like the 20th Century Reanalysis; 20CR). 20CR is one of several tools that we can use to understand weather and climate processes, and hone interpretations about Southern Hemisphere changes.

Ship logbooks from whaling, trade, exploration and migration voyages took regimented observations across the Southern Ocean waters, covering locations where formal land-based stations do not exist. We discuss citizen science transcription of ship log meteorological data progress from our experiences with the Zooniverse-hosted Southern Weather Discovery (www.southernweatherdiscovery.org; SWD) platform. SWD was set up in 2018 as a contribution to ACRE (Atmospheric Circulation Reconstructions over the Earth. Within this platform, volunteers can transcribe typed and handwritten observations that our team has gathered from many archives located world-wide.

In the first SWD phase, thousands of volunteers transcribed >250,000 barometric pressure and temperature observations. These "new" old data are being used in Southern Annular Mode reconstructions and analysis of weather patterns that produced extreme impacts for New Zealand. We describe some preliminary results, and discuss bottlenecks for image preparation, quality control of observations, and data munging. We also introduce the "Week it Snowed Everywhere", a SWD component with aims to consolidate citizen science data transcription lessons and improve handwritten scientific data transcription using artificial intelligence.

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Foraminifera in deglacial sediments: Where can we find in situ calcareous microfossils to date Grounding Zone Wedges?

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Thanks to improved multibeam swath bathymetry, it is now possible to perform targeted coring of glacial landforms. Among them, Grounding Zone Wedges (GZWs) mark grounding line stand-stills that punctuated the progressive deglaciation. For a full understanding of deglaciation processes, it is critical to recognize and date these stand-stills. Following the NBP1502 cruises A and B to the Ross Sea, we examined post-LGM foraminiferal records from almost 30 sediment cores largely from sites near or at GZWs that were different in scale and location. We identified unusual foraminiferal taxa well-fit to survive limited food resources near paleo-grounding lines and influenced by the drainage of subglacial meltwater into the ocean. More importantly, we also recognized environments and geomorphic settings from which in situ foraminifera could be obtained and used for radiocarbon dating. Despite clear differences in post-LGM foraminiferal records between the western and the eastern Ross Sea, it appears that the high bathymetric gradient of GZWs and relative proximity to continental shelf edge were key factors promoting rich benthic foraminiferal communities. This knowledge may enable better core site selection in future studies.

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Exploring the Relationships of Sea Ice Proxies in East Antarctica

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Polar Sea ice plays an important role in the global climate system by acting as climate change indicators. Satellite observations inform us Antarctic sea ice extent has had consecutive maximum sea ice records between the years 2012 to 2014, but experienced a record low in 2016. With satellite data available from 1979, distinguishing long term trends from the noise of inter-annual variability has been challenging. This has led to reconstructions of Antarctic sea ice in the 20th century using proxies from the ice core trace chemical records extracted from the Antarctic ice sheet. Methanesulphonic acid (MSA) is closely linked to biological marine activity and its preservation in the sea ice allows it to be used as a sea ice proxy (Curran 2003, Abrams 2013). Sea salts such as chloride which are stable in the ice sheet, hold potential as proxies for sea ice extent over glacial timescales. Pre-satellite information suggests a decline in Antarctic sea ice over the 20th century although the magnitude of the decline varies regionally.
In this study we explore the relationship between sea ice proxies such as MSA and chloride with sea ice extent at three sites in East Antarctica: Mount Brown South, Aurora Basin North and Dome Summit South. We show that MSA and chloride have significant relationships with the sea ice at these regions which warrant further study. Investigating the variability of sea ice reconstructions from these regions is a vital step towards understanding the regional patterns of long term Antarctic sea ice trends.

1671

The oxygen isotopic variations in a Dome Fuji (Antarctica) ice core – Relationships of the temperature proxy with solar activity and oceanic variations

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Dome Fuji station, one of Japanese research stations in East Antarctica, is located on a summit of Dronning Maud Land at an altitude of 3,810 m a.s.l. (above sea level; 77˚19’ 01” S, 39˚42’ 12” E) and the 10 m depth mean snow temperature is −57.3˚C. The East Antarctic inland area in the vicinity of the Dome Fuji station has been recognized to be very unique: The snow and ice there contain much stratospheric information rather than tropospheric information compared with other Antarctic ice cores.

We present our quasi annually-resolved temperature reconstruction of 1750 – 1940 AD, a period of preindustrial era, based on oxygen isotope measurement on a shallow ice core drilled in 2010 at the 10 km south of the Dome Fuji station. The concerned Dome Fuji ice core called DFS10 is dated by applying volcanic signature matching to transfer the West Antarctic Ice Sheet (WAIS) Divide ice core chronology constructed by annual layer counting. Based on this quasi-annual chronology, we have examined a well-established temperature proxy, δ18O. We found periodicity of ~10 and ~20 years in our time series analyses. In our presentation, we will further discuss the origin of these periods by investigating their cross correlation with solar activity variations and also with Pacific Decadal Oscillation (PDO) that has been known to have ~20 years periodicity, as a representative of oceanic and atmospheric variations.

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Evidence of MIS Late Peistocene Ice Melt from Planktonic Foraminfers impacted by the Totten Glacier outflow over the Sabrina Slope, East Antarctica

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Stable isotope analyses of n. pachyderma from RV Investigator(IN2017-V01), Piston Core #1 (PC01) indicate after preliminary dating, negative delta 18O intervals during Heinrich events 4 and 5 (Epica Dome intervals AIM 8 and 12). We interpret these as indicating meltwater events from the Totten Glacier catchment. The change in delta 18O is on the order of one per mil or more during these events. The core site is located on the continental slope seaward and slightly west of the Totten Glacier in an area likely to be on the path of water moving from the front of the Totten, at a depth of 2163m. Typically, preservation of foraminifera is relatively rare in slope sediments that are close to the ice edge, however during the meltwater events foraminiferal preservation is good and the foraminifera are abundant. We suggest that the stratification established by the meltwater plumes diminishes the productivity of the diatom assemblages and reduces the flux of organic matter to the sea floor locally, which aids in the preservation of the foraminifera in the sediment underneath the plume. That significant meltwater can reach the slope region off the East Antarctic margin is a surprise given how cold and stable the East Antarctic margin is perceived to be and implies a much more dynamic East Antarctic ice sheet than previously thought.

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An expanded view on the Orbital Response of West Antarctic Ice Sheet Dynamics during the Mid- to Late Pliocene

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International Ocean Discovery Program Site U1524 is located on the eastern levee of the Hillary Canyon system, which acts as a major conduit for newly formed Antarctic Bottom Water (AABW) and its export into the Southern Ocean. We present an integrated sedimentological (lithofacies and grain size), inorganic geochemical (XRF), and organic geochemical (TOC and bulk carbon and nitrogen isotopes) datasets that demonstrate the significant role changes in southern hemisphere seasonal insolation had on the West Antarctica Ice Sheet (WAIS) during the mid- to Late Pliocene.

The “warm” mid-Pliocene 3.0-3.3 Ma is characterized by 100,000 year paced lithological changes and low amplitude 100,000 year variability in our iceberg rafted debris (IBRD) mass accumulation rate (MAR) record. The low amplitude variability IBRD MAR record is mostly likely a consequence of a retreated ice margin when relatively warmer than modern surface ocean conditions enhanced melt out of ice bergs close to the margin. Whereas, after 3.0 Ma the gradual increase in terrigenous mud content and large amplitude 100,000 year IBRD MAR cycles is consistent with evidence from the AND-1B record of a dynamic ice margin with large scale fluctuations in ice sheet extent and retreat superimposed on southern ocean cooling trend. The orbital pacing in our record is consistent with new far-field Pliocene sea level reconstructions and both deep ocean and surface ocean changes occurring the Pacific Ocean sector that appear to be decoupled from the globally integrated benthic d18O stack record.

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Million Year Ice Core: Australia's oldest ice core project

Joel Pedro[1], Tas van Ommen[1], Mark Curran[1], David Etheridge[2], Jason Roberts[1], Ben Galton-Fenzi[1], Lenneke Jong[1], Andrew Klekociuk[1], Gil Logan[1], Tim Lyons[1], Andrew Moy[1], Chris Plummer[3], Tessa Vance[3], Steven Whiteside[1], Nerilie Abram[4], Ian Goodwin[5], Andrew Smith

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The aim of Australia's Million Year Ice Core (MYIC) project is to recover a continuous Antarctic ice core reaching beyond 1.2 million years into the past. Obtaining such a record is a deliverable of the Australian Antarctic Science Strategy and a key priority of the International Partnership in Ice Core Sciences. The MYIC will extend the Antarctic continuously-dated ice core record beyond the current 800,000 years and across the Mid Pleistocene Transition, during which the pacing of glacial cycles changes from 41,000 to 100,000 years. Resolving the cause of this non-linear shift in the Earth's climate state is the major scientific motivation of the project.

The MYIC project is collaborating with the European Beyond Oldest Ice (BE-OI) project and the US Ice Drilling Program in accordance with IPICS call for two or more oldest ice cores. The target drilling sites for MYIC and BE-OI are in the 'little Dome C' region (~30km south of Dome Concordia Station) where collaborative radar surveys and modelling indicate million-year-old ice is likely present in a ~2.8 km-deep stratigraphically-continuous profile. The suite of MYIC measurements will include the primary greenhouse gases and their isotopes, temperature and climate proxies, radionuclides, volcanic markers and tracers of crustal weathering.

The project is led by the AAD, partnering with CSIRO and UTAS, with ongoing development of other national and international collaborations. The presentation will update the community on drill development, MYIC science and collaborative opportunities. We hope to stimulate discussion and engagement with the broader Antarctic science community.

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Late Holocene climate variability inferred from lake sediments in Lützow-Holm Bay, East Antarctica

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Lakes in coastal ice-free regions of Antarctica sit at the boundary of the continent and the oceans, providing an opportunity to fill a spatial gap between palaeoclimate records derived from ice cores and those from lower latitudes. High resolution records have been developed from the sediments of Lake Hamagiku and Lake Naga in Lützow-Holm Bay, East Antarctica, tracing environmental change through the last 3000 years. These reconstructions are based on sedimentary diatom species composition and bulk organic matter carbon and nitrogen isotope ratios. These records of past environmental change are supported by an investigation into the modern relationship between diatom assemblages and their habitats and lake water chemistry. Specific conductivity was found to be the primary factor explaining variations in diatom assemblage. Diatom assemblages were also found to significantly differ between the littoral region and the lake floor deeper than two metres water depth. Both lakes record a coherent and sustained shift in fossil diatom assemblage at ~1800 cal. yr BP, interpreted to reflect an increase in the duration of ice-free conditions associated with regional warming. Lake productivity, inferred from diatom valve concentrations and isotope geochemistry, appears to be stable through this time period however, which is attributed to limitations imposed by low nutrient conditions. Periodicity with a wavelength of ~250 years was identified in the records from both lakes. These periodicities are consistent with those reported from a range of Southern Hemisphere paleoclimate records and reconstructions, and have been associated with both solar activity and Southern Hemisphere westerly airflow.

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Eight centuries of hydroclimatic variability recorded in a southwest Australian speleothem with an annually resolved chronology

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Speleothems from Golgotha Cave in SW Western Australia have been investigated to extend our knowledge of past climate variability for this region during the last millennium. A challenge in their interpretation has been the disagreement between these records despite representing coeval growth from within the same cave. This presentation will focus on a record (GL-S4) that grew continuously over the past eight centuries determined by counting annual chemical laminations. The paleoclimate interpretation of GL-S4 is informed by long-term monitoring of Golgotha Cave to characterise the hydrology[1-5], hydrochemistry[5,6], rainfall water isotopes[7] and the development of proxy system forward models[1,8]. A principal components analysis demonstrates that the dominant variability in the GL-S4 geochemical record is attributable to hydroclimate (PC 1), soil connectivity (PC 2) and bedrock weathering (PC 3). These results provide eight centuries of baseline data to extend our knowledge of past hydroclimate variability for this region that is currently experiencing a prolonged decrease in rainfall.

1701

Late Pleistocene and late Pliocene records of glacial-interglacial paleotemperatures and depositional processes in the outer Amundsen Sea from diatom morphometrics and sedimentary microfabrics

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Drilling in the outer Amundsen Sea, IODP expedition 379 recovered Upper Pliocene and late Pleistocene biosiliceous records that document oceanographic changes coincident with dramatic glacial-interglacial changes in the West Antarctic Ice Sheet (WAIS) and the Southern Ocean. We are generating preliminary paleotemperature records for the last 620 kyrs (representing Marine Isotope Stages 15 (MIS-15) to MIS-4) from quantitative morphometric analysis of the dominant Pleistocene diatom Fragilariopsis kerguelensis, following techniques pioneered by Kloster and colleagues (2014; 2018; 2019). Utilizing the SHERPA image processing and analysis package, we assess two distinct morphotypes that have been shown to correlate with temperature and water mass. We have reason to believe that a significant amount of these diatoms are advected from the upwelling zone further offshore, rather than recording local production, thus the record may be useful in tracking changes in southward advection of diatoms in Circumpolar Deep Water; a primary influence on marine ice sheet instability.

Many Late Pliocene interglacials here are characterized by a strong association of enhanced ice-rafted detritus (IRD) coincident with very high diatom productivity. Using continuous light and scanning electron microscopy through key intervals we are documenting microfabrics that demonstrate a direct link between enhanced iceberg production and diatomite accumulation. This strong correlation may indicate that WAIS collapse events and iceberg melting, especially in the late Pliocene, enhanced nutrient availability to the Southern Ocean, either directly from the continent or by changing upwelling or current patterns associated with ice sheet retreat.

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A first insight into mercury atmospheric deposition in lakes from sub-Antarctic Macquarie Island

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Mercury is a potent neurotoxin with a high rate of bioaccumulation and biomagnification in food chains, causing serious health issues for wildlife and human populations. The atmospheric residence time of elemental mercury is several months to a year, and therefore it can travel long distances in the atmosphere and be deposited to remote locations such as the Antarctic region. In this study we measured mercury concentrations and fluxes in sediments of two lakes on sub-Antarctic Macquarie Island (Lake Tiobunga and an unnamed lake in the northwest, Lake 1) to examine the influence of climate and anthropogenic activities on mercury deposition. Mercury fluxes in the last 3,000 years varied from 4 to 26 (ug-1m2 yr-1), with the highest fluxes recorded between ~600 and 300 cal yr BP (1400-1700 CE). Mercury fluxes also increased in the last 100 years, suggesting the influence of anthropogenic effects such as industrial emissions and long-distance transport, as well as erosional inputs associated with the activities of introduced rabbits. Lakes from other sub-Antarctic islands need to be studied to provide a refined history of the effects of climate and wind strength on mercury deposition in the sub-Antarctic region, as well as to decouple the anthropogenic influence on mercury deposition in Macquarie Island in the last 100 years.

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Antarctic climate response to large volcanic eruptions in the historical period

Antarctic Climate Response To Large Volcanic Eruptions In The Historical Period Natalia Silva[1], Antarctic Climate Response To Large Volcanic Eruptions In The Historical Period Ilana Wainer[1], Antarctic Climate Response To Large Volcanic Eruptions In The Historical Period Myrian Khodri[2]
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Large tropical volcanic eruptions are well known to change the global climate and maybe even interfere with some natural modes of variability such as El Niño Southern Oscillation. As they inject a high amount of sulfur gas into the stratosphere, sulfate aerosol loading increases a few months after the eruption, which is then transported globally. Large tropical events may, therefore, affect extratropical climate variability. For example, temperature changes have been identified in Antarctica after the Pinatubo eruption in 1991, as warming in the peninsula. However, a causal link with the eruption and, more generally, a possible influence of large tropical volcanic eruptions on the Southern Hemisphere climate are still open questions. In this study, we aim to focus on the five biggest eruptions of the historical period (Krakatau — Aug/1883, Santa María — Oct/1902, Mt Agung — Mar/1963, El Chichón — Apr/1982 and Pinatubo — Jun/ 1991) by assessing two CMIP6 class models (IPSL-CM6A-LR Large Ensemble and BESM) and two Reanalyses (NOAA 20th Century Reanalysis and ECMWF's ERA 20th Century).

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Diatoms in Ice Cores, a new proxy for reconstructing past wind strength in the Amundsen-Bellingshausen Seas region, Antarctica

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In the last decade, several efforts have been carried out to assess the causes of the current rapid recent warming measured on West Antarctica and Antarctic Peninsula. The increase in wind strength and shifts in atmospheric circulation patterns have shown to play a key role in driving the advection of warm air from mid-latitudes to high-latitudes. Winds are also responsible for driving surface melting in the ice shelves, enhancing the removal of surface snow, and for promoting basal melting through the upwelling of deep warm water. All these combined have shown to produce substantial effects on environmental parameters, such as sea surface temperatures, sea ice extension, air surface temperatures and precipitation.

Even though winds are fundamental components of the climatic system, there is a lack of reliable long-term observational wind records in the region. This has hindered the ability to place the recent observed changes in the context of a longer time frame.

In this work, we present records of marine diatoms preserved in a set of ice core retrieved from the southern Antarctic Peninsula, the Ellsworth Land region and sub-Antarctic Islands. The diatom abundance and species assemblages from these ice cores prove to represent the local/regional variability in wind strength and circulation patterns that influence the onshore northerly winds. We use this novel proxy to produce an annual reconstruction of westerly winds in the Amundsen - Bellingshausen seas region during the last two centuries.

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Bottom water oxygenation changes in the Southern Indian Ocean over the last glacial cycle: implications for the efficiency of the ocean biological carbon pump

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A larger remineralized carbon pool in the deep glacial ocean has been related to a more efficient sequestration of CO2, yet the interplay and dynamics of potential mechanisms responsible for this drawdown such as a slower glacial overturning circulation and/or a more efficient biological carbon pump remain elusive. Bottom water oxygenation reconstructions based on redox-sensitive trace metals can help decipher the relative contribution of these processes on the magnitude and efficiency of the partitioning of carbon between the ocean and atmosphere. We present downcore manganese (Mn) and authigenic uranium (aU) records from the last glacial-interglacial cycle based on three sediment cores retrieved in the vicinity of the Kerguelen Plateau in the Southern Indian Ocean covering a transect from the Antarctic to the Subantarctic Zones. For the Subantarctic and Polar Frontal Zones, we report higher bottom water oxygenation during interstadials and lower oxygenation during glacial periods. Compared with export production reconstruction, this suggests a dominant influence of ventilation changes compared to local export production on sedimentary redox conditions. Export production may have entailed a secondary influence on bottom water oxygenation during terminations as a result of enhanced aeolian Fe supply at our core sites, enhancing by inference the respiratory oxygen demand associated with organic matter remineralization. In the Antarctic Zone, we cannot detect a coherent glacial-interglacial bottom water oxygenation pattern. The robustness of trace-metal reconstructions may be limited due to the shallow core location exposed to temporally varying water masses and thereby affecting oxygenation patterns.

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A new dinoflagellate cyst-based transfer function for the Southern Ocean: Quantifying sea surface temperature, sea-ice and nutrient availability

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Dinoflagellate cyst assemblages are widely used to reconstruct past marine environmental conditions. Most of these reconstructions have been qualitative, limiting their potential and impeding immediate comparison to other proxies. As dinoflagellate cysts are often continuously present in past sediments, a new quantitative approach would greatly improve the reconstruction of past ocean conditions.

Here, we present a novel way to better quantify sea surface temperature, sea ice and nutrient availability for the Southern Ocean based on modern sedimentary dinocyst assemblages. We combine previously published (Marret et al., 2019) and new surface sedimentary dinoflagellate cyst assemblages from the Southern Indian Ocean and the Ross Sea, increasing the spatial coverage of ice-proximal locations, with a novel way to assess the connection of sedimentary particles to the overlying water. Lagrangian particle trace simulations in high-resolution (1/12°) ocean models allow us to account for lateral transport by ocean currents and thus lead to a more accurate identification of surface water source regions of the sedimentary dinocyst assemblages.

We now make use of several statistical means, such as a bayesian approach, to further detect, separate and improve correlations between the new database of modern dinocyst assemblages and environmental conditions. Eventually, we compare these results to existing techniques (such as the modern analogue techniques or weighted averaging–partial least squares) in order to translate dinocyst assemblages to quantitative paleoceanographic conditions.

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Climate variability in Antarctica and the Southern Hemisphere over the past 2000 years (CLIVASH2k)

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The CLIVASH2k working group is part of the PAGES 2k network. We aim to improve our understanding of large-scale modes of climate variability and the mechanisms and drivers of climate change in Antarctica, the sub-Antarctic and the wider Southern Hemisphere during the past 2000 years. We build upon previous PAGES syntheses documenting changes in Antarctica over the past 1000-2000 years to focus on the mechanisms driving climate variability. The working group is open to anyone working on climate variability in the southern hemisphere and currently consists of paleoclimateologists working on a range of archives (ice cores, marine sediments, lake sediments, and peat and moss banks), climatologists and climate modellers. Come along to the poster for more information and ways to get involved.

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The 14CO2 bomb pulse in firn air and ice at Aurora Basin North, East Antarctica.

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In modern times, the natural radiocarbon (14C) cycle has been perturbed by the large-scale combustion of fossil fuels during the industrial period and more recently by nuclear technologies. The above-ground testing of nuclear weapons during the 1950s and 1960s doubled the amount of 14C in the atmosphere and this 'bomb-pulse' of 14CO2 has been taken up in plants through photosynthesis. It has also been incorporated in air in open pores of firn before close-off in bubbles in polar ice sheets. Due to its rapid onset and known decline, the pulse provides a powerful constraint to quantify the smoothing of atmospheric CO2 signals due to firn diffusion and bubble close off. The degree of smoothing determines the time resolution with which trace gas histories can be reconstructed from ice cores. When used to tune a firn air diffusion model, the measured 14CO2 'bomb pulse' also permits accurate dating of CO2 and other gases in the air record.

Here we report on the extraction of CO2 from Aurora Basin North (ABN) firn air and ice core air bubbles. As expected, results suggest the age spread at ABN is wider than higher accumulation sites, such as Law Dome. Firn modelling has been completed and the 14C results have been incorporated to help determine (with other gas measurements) the age and age spread of air in firn and ice at ABN. Measurements at ABN will also help confirm variations measured in other cores such as at Law Dome.

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Exploring Past Connections between Productivity and Iron Supply at the Subtropical Front

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Dust can affect the global climate through several ways amongst which fertilization of the HNLC regions by iron-bearing dust is an important one. However, present-day iron-fertilization experiments have failed to reproduce a large-scale, sustained productivity increase that would result in substantial CO2 drawdown. One of the major questions is whether a significant portion of the organic carbon produced in the surface waters due to nutrient utilization is exported below the mixed layer and preserved in underlying sediments. In this scenario, the response of productivity to the past episodes of iron-bearing dust increase can provide a clue. Here we present a record of nutrient utilization (nitrogen isotope ratio of sedimentary organic matter) and consequent productivity variability and its preservation (total organic carbon and nitrogen content of bulk sediment) from the Subtropical Front of the Indian Ocean sector of the Southern Ocean (42 °S latitude and 48 °E) for the past 71 kyr. We find that the nutrient utilization and productivity preserved in the sediments are strongly coupled. We further compare our results with the EDC dust flux representing global dust concentration and ODP1090 Fe mass accumulation rate (MAR) from the Atlantic sector of the Southern Ocean representing iron-bearing dust input in the Southern Ocean. We find that nutrient utilization increases during glacial periods along with the iron-bearing dust supply, which is accompanied with high productivity. The close correspondence between these records reveals a possible connection between aeolian dust influx and global climate via natural iron ocean fertilization.

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High-Resolution Paleoceanography of the Falkland Slope and the Scotia Sea during Pleistocene based on IODP Expedition 382

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Iceberg alley and Sub-Antarctic zone of South Atlantic is a key modulator for the global climate. The sensitivity and the importance of this region to the climate change have been a significant topic of research with respect to past, present and future climate. The studies related to long term climate reconstructions and frontal movement during the glacial-interglacial cycles are lacking in the Iceberg Alley. Resolving changes in the transition of various fronts located in the region is crucial for advancing our understanding of the Southern Ocean's role in affecting ocean and climate change on a global scale. Diatom-bound δ15Ndb was used to reconstruct the glacial-interglacial nutrient utilization variability of the Subantarctic Zone. Earlier down-core records from the Southern Ocean showed δ15Ndb variability of 5 to 6 ‰ during the Last Glacial Maximum. The δ15Ndb values decreased to values as low as 2 ‰ during the glacial terminations. Changes in nutrient utilization may have resulted from atmospheric dust influx and/or decreased mixed layer depths associated with sea ice melting. Enhanced nutrient consumption during glacial periods in Sub-Antarctic regions would have lowered the concentration of CO_2 in the atmosphere. We will present here the δ15Ndb and δ15N-SOM of the scrape sediment and squeezed cake samples retrieved during IODP expedition 382 spanning the timespan of Pleistocene.

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Synoptic climatology of the Southern Indian Ocean and potential links to East Antarctic ice cores

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Interpretation of eastern Antarctic ice-core palaeoclimate proxies can be improved through better understanding of the synoptic-scale dynamics and variability of the Southern Indian Ocean. In the case of high-resolution (seasonal to annual) ice-cores, this is especially important, as event-scale precipitation and redistribution of surface snow can enhance or weaken links to regional climate processes. Two high resolution ice-cores in East Antarctica, Law Dome and Mt Brown South (MBS), provide an opportunity to extend and broaden our understanding of Southern Indian Ocean synoptic variability prior to the modern satellite era (post 1979). However, limited understanding of the variability of synoptic processes (daily to decadal) influencing the East Antarctic ice-cores and how these are preserved in ice cores hampers the interpretation of palaeoclimate proxies. Here we present results from a synoptic typing study for the Southern Ocean region between 40°E and 180°E – the 'atmospheric catchment' region for both Law Dome and MBS. Our results describe regional synoptic conditions, ranging from meridional, mixed and zonal patterns. The zonal and mixed patterns were strongly correlated with the Southern Annular Mode (SAM); however, the regional synoptic representation of positive SAM conditions is not zonally symmetric. Additionally, our results indicate that during austral spring and summer, the meridional patterns have stronger relationships with tropical modes of climate variability (i.e. Indian Ocean Dipole, El Nino Southern Oscillation) compared to SAM. These results are useful for East Antarctic atmospheric transport and climate variability research, in particular for improved interpretation of East Antarctic ice-core climate proxies.

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Evidence of Southern Hemisphere lead in a millennial-scale warming event of the last glacial period

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The Northern Hemisphere millennial-scale climatic oscillations of the last ice age, known as 'Dansgaard-Oeschger' (DO) events, and their Southern Hemisphere counterparts, 'Antarctic Isotope Maxima' (AIM), are characterized by their distinct phase relationship known as 'bipolar seesaw'. A recent study taking advantage of high-resolution ice core records from Antarctica and Greenland, suggests that DO-AIM events are initiated in the Northern Hemisphere. Here, we present the relative timing of these events in Roosevelt Island Climate Evolution (RICE) and Northern Greenland Ice Sheet Project (NGRIP) isotope records between 26-40 kilo years before present (ka BP 1950 AD). The well-constraint RICE age model and continuous flow methane record provide an opportunity to examine the relative phasing during AIM-DO4. We demonstrate that RICE cools 209±81 years prior to the onset of this Greenland interstadial, which could indicate the Southern Hemisphere initiation of these events, and nuances the generic Northern Hemisphere push. We propose that the influence of water column stratification resulting from sea-ice melt on areas of open-ocean convection as the major causal mechanism for the weakening of the southern limb of overturning circulation in the Ross Sea. Additional factors may have also contributed to the build-up of water column stratification in the region, such as local insolation changes and ice sheet melt. Our results show that the evolution and relative phasing of individual DO-AIM events varies, providing additional insights into the drivers of these events.

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An Interdecadal Pacific Oscillation reconstruction spanning the last two millennia

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The Interdecadal Pacific Oscillation (IPO) is a nominally 15-30 year climate mode identified through analysis of Pacific sea surface temperatures over the past 150 years. It is unclear whether the IPO is a true oscillation or simply the low frequency response of the climate system to forcing, principally ENSO. Nonetheless, the IPO has clear climate impacts, one example being hydroclimate variability in Australia. In positive phases of the IPO, drought risk is heightened due to a reduction in the likelihood of large, recharging La Nina-derived rainfall events. In negative phases, flood risk in Australia is greatly increased due to an increased likelihood of such rain events.

Previous work derived a 1000 year, reconstruction of the IPO from multiple palaeoclimate archives from the Law Dome ice core in East Antarctica. This reconstruction allowed the assessment of the true risk of drought- and flood-prone epochs in Australia. Subsequently, an entirely independent reconstruction of the IPO was developed using SE Asian tree records by Buckley et al. (2019), spanning most of the last millennium. The fidelity the two reconstructions display with respect to the instrumental IPO record and each other suggests both are representing IPO variability. Here we present an IPO reconstruction that doubles the temporal span of existing reconstructions to cover the last 2000 years using newly analysed and dated material from the Law Dome ice core. This new, longer reconstruction identifies important features of Pacific decadal variability that have significant implications for understanding hydroclimate epochs across Australasia and the Pacific region.

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High spatial and temporal variability of surface mass balance at ice rise and promontories in Dronning Maud Land (East Antarctica): precipitation vs. post-depositional processes

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The surface mass balance (SMB) is one of the largest sources of uncertainty when determining the Antarctic ice sheet total mass balance and thus Antarctica's contribution to sea level rise. Here we present a reconstruction of surface mass balance at two ice promontories located in Princess Ragnhild Coast (Dronning Maud Land). To reconstruct the SMB history, we first date our ice cores using a suite of seasonal parameters (water stable isotopes, major ions and ice conductivity). Annual layer thickness is then converted into meter water equivalent using the measured density profile and by accounting for ice deformation at depth using strain rates. The latter are obtained from ice dynamical modelling at the ice divide and differential OPTV measurements from repeated surveys in the borehole.
The resulting SMB reconstructions exhibit a large interannual variability without any trend over the last 50 years for both promontories. This is in sharp contrast with the SMB reconstruction from the Derwael Ice Rise (located at 90 km from our easternmost promontory) that showed a significant SMB increase since the 1950's, consistent with expected snowfall increase as a result of higher temperatures (Philippe et al., 2016). Different factors may contribute to these contrasting results over a relatively short distance, such as variability in precipitation regime (e.g. atmospheric rivers) and/or post-depositional processes (e.g. wind erosion). Such large discrepancies over short distances of the order of spatial resolution of global atmospheric models have major implications for understanding precipitation changes across the Antarctic ice sheet.

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Ice core biomarker constraints on past sea ice change in the Ross Sea

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Ice core biomarkers show great promise for reconstructing marine primary productivity and sea ice change in Antarctic waters. A novel ice core biomarker based on spectroscopy of fluorescent Organic Matter (fOM) paired with Imaging Flow Cytometry (IFC) offers new information on changes in microbiota transported in the atmosphere and deposited in Antarctic snow. Here we provide the first results of fOM from the Roosevelt Island Climate Evolution (RICE) ice core recovered from the northern margin of the Ross Sea. The 10 m firn core record of fOM captures marine variability over the past 50 years. We outline our plans to extend the fOM record to the past 2000 years providing constraints on marine primary productivity and sea ice change. Correlation of the RICE record with annually resolved marine sediments will extend the relatively short observational record of sea ice in the Ross Sea region improving our understanding of regional climate variability.

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The sensitivity of the early Cenozoic Southern Ocean to Tasman Gateway depth and wind stress

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Ocean circulation is largely modulated by the distribution of continents and seafloor topography. Tectonic motions of continents through the Cenozoic led to the opening of gateways between major ocean basins, causing the alteration of global ocean circulation. While the role of Tasman Gateway deepening has been modelled in the past, the role of wind stress in the Southern Ocean has not yet been investigated. Here, we use an eddy-permitting model (0.25°) with relatively realistic paleobathymetry to investigate the evolution of the Cenozoic Southern Ocean under the gradual deepening of the Tasman Gateway and latitudinal modifications of wind stress. We find that clockwise polar gyres exist in both Pacific and Indo-Atlantic sectors of the Southern Ocean. The latitude of the wind band affects the size and strength of the gyres. As the wind band moves southward, the gyres get shrunk, while the strength is intensified. A strong eastward current develops under the synergistic actions of gateway deepening and wind stress shifts to the south. The influence of the latitude of the wind band is particularly noticeable when the Tasman Gateway is deep at 1500 m, where a 5 degree southward shift causes a strengthening of this interbasinal current by about 20 Sv. Furthermore, we propose that it is the latitude of maximum westerly wind relative to the northern margin of the deep Tasman Gateway that controls the strength of the throughflow.

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Antarctic sea ice variability during the past 200 years

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In contrast to the Arctic, where total sea ice cover has been decreasing since systematic satellite observations began in the late 1970s, Antarctic sea ice has shown a steadily and significant increasing trend from 1979 to 2014, followed by a precipitous decline after 2014. However, the observational period is too short to evaluate the sea ice variability and its drivers over decadal to multi-decadal time scales. In this study, ice core and fast ice records are used to reconstruct the latitude of northernmost sea ice extent (NLSIE) for different sectors of the Antarctic, including the Indian and west Pacific (IndWPac), Ross Sea (RS), Amundsen Sea (AS), and Weddell Sea (WS). We analyze the linear trends of the NLSIE for the past 100~200 years (-0.03°, 0.02°, 0.07°and -0.08° per decade for the IndWPac, RS, AS, and WS respectively) and identify possible regime shifts using a sequential data processing scheme. Our results suggest that the NLSIE trend in all sectors accelerated after the mid-20th century. The rapid decreasing trend in IndWPac was associated with the positive shift of Indian Ocean Dipole (IOD) and Southern Annular Mode (SAM). The increasing trend in RS and AS, and the decreasing trend in WS was associated with the multi-decadal variability of Interdecadal Pacific Oscillation (IPO) and the positive trend of SAM.

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Identifying atmospheric processes favouring the formation of physical features in the Mount Brown South ice core.

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The features preserved in ice cores provide crucial and unique records about the past atmospheric variability, offering the possibility to increase knowledge of the climate system and better predict future climate changes. Consequently, understanding the link between features in ice cores and the atmospheric processes causing them is key to interpreting the palaeoclimate information preserved in Antarctic ice. Ice cores from Mount Brown South (MBS), East Antarctica, were drilled to help understand the past atmospheric circulation variability in the southern Indian Ocean and southwest Pacific Ocean. In addition to chemical and isotopic records, high-resolution images of the ice core were made using an Intermediate Layer Ice Core Scanner (ILCS). Upon physical inspection of these images, there are visible bubble-free layers occurring frequently multiple times a year, and the origin of these features is still unknown. This project aims to determine whether the bubble-free layers in the MBS ice core can be related to atmospheric processes. We use the newly available reanalysis products (ERA5) from the European Centre for Medium range Weather Forecasts (ECMWF) to investigate the occurrence of atmospheric processes in the Mount Brown region including temperature inversions, wind scour and accumulation hiatuses. We dated the ice cores using multiple annual chemical and isotopic horizons, and then used ERA-5 regional accumulation to estimate the season that the bubble-free layers occurred during 1979-2017. This information is used to detect the weather patterns occurring when the layers were formed in order to identify the most likely processes causing the bubble-free layers.

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Magnetostratigraphy and Environmental Magnetism Study of Hole U1524A from IODP Expedition 374

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IODP Expedition 374 aims at resolving the Ross Sea ice sheet history since the Miocene. Hole U1524A is cored ~120 km north of the Ross Sea continental shelf edge, providing important materials to reconstruct the ice sheet variability and corresponding driving forces. To determine the age of the cores of U1524A, U-channel samples were taken from the top 8 cores and discrete cube samples were taken from the rest of cores. The natural remanent magnetization (NRM) of the samples are AF-demagnetized in order to determine the characteristic remanent magnetization (ChRM) upon which the magnetostratigraphy is built. The NRM of the majority of samples are effectively demagnetized up to 80 mT. It is observed that most samples carry pronounced overprints at the low coercivity range (< 10 mT), with weak signals left for ChRM determination. Detailed rock magnetic experiments suggest that ChRM of weakly magnetized samples are often suspicious. We attempted to correct the ChRM of weak samples in order to extract the geomagnetic information from noisy data. Finally, three major normal/reversed polarity sequences are identified (down to the bottom of Core 30), which suggests the bottom of Core 30 was deposited in the Mammoth Subchrons that is about 3.3 Ma ago.

In addition, the magnetic properties of representative samples of Hole U1524A were compared with sediments from Antarctic Circumpolar Current in the Central South Pacific sector retrieved by IODP Expedition 383. The environmental connection between the Ross Sea and the far-field region are discussed based on the magnetic properties.

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Antarctic Science - Global Connections

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SESSION 7

SOUTHERN OCEAN CIRCULATION: CHANGE AND CONSEQUENCES

Marcos Tonelli
Marina Noro, Tiago Dotto

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Observations of Weddell Sea Deep Water export through Orkney Passage: 2004-present

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Much of the Antarctic Bottom water that reaches large parts of the World Ocean is formed in the Weddell Sea. Orkney Passage, a 3650-m deep gap in South Scotia Ridge, east of the South Orkney Islands, is a key export region of Weddell Sea Deep Water (WSDW). Since 2004, moorings have made continuous observations in this region, with the aim of shedding light on variability in deep water properties and export rates. Coincident with these moored records are full water column profiles from ship-based profiling instrumentation, and in 2017 near-bottom measurements were obtained from the Autosub Long Range autonomous underwater vehicle. These observations have been pivotal for elucidating the water mass transformation processes that take place as WSDW flows through these areas of extremely steep bathymetry. Finally, nearby repeat hydrographic sections crossing South Scotia Ridge have revealed details of links between the variability of abyssal water masses in the Weddell Sea and lighter water masses that are able to reach the Scotia Sea. In this study, we present an overview of our observations in this region, followed by a discussion of the most probable causes of the observed variability in deep water properties.

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Transport of inorganic carbon with Dense Shelf Water from the Adélie Land coast, East Antarctica

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Dense Shelf Water (DSW) supplied from Antarctic coastal polynyas is a key component of the formation of Antarctic Bottom Water, contributing to global meridional overturning circulation. In this study, the export of dissolved inorganic carbon with DSW from the Mertz and Ninnis Polynyas on the Adélie Land Coast in East Antarctica is quantified. Shipboard observations from two summer surveys in 2015 and 2017 were paired with model-derived DSW transport estimates to explore the offshore and cross-shelf fluxes of inorganic carbon. Fluxes of inorganic from the shelf were associated with DSW export through the northern boundary across the Adélie and Mertz Sills, with an additional westward transport from the Mertz through the D'Urville Trough Sill. The source of inorganic carbon to DSW is mainly derived from inflowing modified Circumpolar Deep Water in the mid-layer of the water column, with additional contributions from brine rejection during sea ice formation. This work suggests that Dense Shelf Water export serves as a conduit for the offshore transport of dissolved inorganic carbon, thereby connecting the atmosphere and the surface waters on the shallow Antarctic continental shelf with the deep ocean.

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Rates and mechanisms of mixed layer development in the Drake Passage sector of the Southern Ocean

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The Southern Ocean is known to be a key region for the subduction and obduction of heat and carbon into and out of the ocean's interior. These processes are strongly governed by the deepening and shoaling of the ocean's mixed layer, which is known to respond both to surface forcing and to submesoscale fronts (scale of 1-10s km) that are present in the ocean's interior. Here, we present a unique time series of ship, surface vehicle and underwater glider measurements collected in the vicinity of the Southern Antarctic Circumpolar Current Front (SACCF) in Drake Passage for two months in 2017-2018, which tracked the development of the mixed layer during the early summer season. The autonomous vehicles were piloted so as to quantify both the background mesoscale and small-scale submesoscale gradients, and were supported with high-quality flux measurements from the ship and meteorological measurements from a WaveGlider. The results show significant high-frequency variability in mixed layer depths during the deployment, with indications suggesting this is coupled to the surface wind forcing. The wind data are analysed to assess the contribution of Ekman buoyancy fluxes in promoting submesoscale instabilities, and the accompanying glider temperature, salinity and velocity measurements are analyzed to determine the susceptibility of the flow to a variety of instability processes. We discuss the implications of these processes for heat subduction into the Southern Ocean on seasonal timescales.

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The Southern Ocean in Global Climate: The ORCHESTRA Programme

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The Southern Ocean accounts for around half of all oceanic uptake of carbon, and more than three-quarters of the heat uptake. Despite its profound importance, the Southern Ocean is also the least measured and arguably the least understood of the world's oceans: its remoteness and inhospitable nature have led to a dearth of sustained, strategic measurement programmes, and the small-scale and complexity of many of the key processes have precluded the desired advances in simulation. To address these issues, a £10M programme funded by the United Kingdom
NERC is underway - 'Ocean Regulation of Climate by Heat and Carbon Sequestration and Transports (ORCHESTRA)'. ORCHESTRA spans five years (2016-2021) and is using combination of novel data collection, analyses, and computer simulations to radically improve our ability to measure, understand and predict the circulation of the Southern Ocean and its role in the global climate. It is making unique and important new measurements in the Southern Ocean using a range of techniques, including basin-wide ocean/carbon/tracer sections, as well as deployments ofautonomous vehicles, meteorological aircraft, seal tagging and other innovative techniques for collecting data. It also involves the development and use of advanced ocean and climate simulations, to improve our ability to predict climatic change in coming decades. This poster will outline the
rationale and key results from the ORCHESTRA programme to date.

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Physical properties of the eastern Ross Sea observed during the ESTRO project

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During the last decades, the Ross Sea Dense Shelf Water, a precursor to AABW, experienced a steady salinity decline. Recent observations show a striking salinity increase from 2016. Besides the negative salinity trend and the recent rebound, coherent fluctuations with a time-scale of 5–10 years were observed. A quantitative estimate of the terms contributing to the Ross Sea salt budget is necessary to understand the physical mechanisms responsible for these changes. A crucial area to investigate is the eastern Ross Sea, where the inflow of freshwater from the Amundsen Sea (ASW) occurs, and where the lack of observations is still a major issue. In January 2020 the ESTRO project conducted for the first time a synoptic oceanographic survey in this area. Its main objective was to characterise the inflow of Circumpolar Deep Water and ASW, to assess the vertical mixing of these water masses, and to define their contribution to the freshwater budget. Here we present hydrographic and current observations collected during the cruise. These observations extended north-south across the shelf break from east of Cape Colbeck (155°W) to 165°W and east-west along the Ross Ice Shelf (RIS) from the Bay of Whales to Ross Island. In addition, a glider was used to complete a transect between the RIS and the shelf break. The ASW characterized by salinity of 34.12 and potential temperature of -1.86°C was identified in a 200m layer centred at 150m depth. These observations will be discussed within the context of the (few) previous ocean observations available.

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Pushing SOOS to its limit: what can we see with the current Southern Ocean Observing System?

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The Southern Ocean is known to be one of the most data-sparse ocean basin. Even in the era of Argo floats, the density of in-situ observations in the Southern Ocean remains substantially lower than those of other major basin, particularly in seasonally ice covered regions, and during the austral winter.

What physical processes and ocean structures can we "see" with the current Southern Ocean Observing System (SOOS) and how can the system be improved? Here, we assess the current and some hypothetical future observing systems through a series of simple Observing System Simulation Experiments (OSSEs): a realistic, high resolution ocean model is sampled using the historical distribution of ship based, Argo float and instrumented marine mammal profiles to create a database of "virtual" temperature and salinity profiles. The ocean state is then reconstructed from these "virtual" observations using a sophisticated optimal interpolation technique, which can then be compared to the "true" model state.

By selectively withholding various platforms within in-situ database, sub-sampling observations to degrade the observing network, and removing observations from selected regions, we can assess how many in-situ observations we require to effectively "see" the large, medium and small-scale ocean structure, as well as where these observations must be taken. Various hypothetical future scenarios are presented (such as a doubling of the number of Argo floats) to inform improvement of the observing system.

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Freshening and cooling effect of Vincennes Bay Bottom Water on the layer of Antarctic Bottom Water in the Australian-Antarctic Basin

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Inter-annual variability of Antarctic Bottom Water (AABW) properties off the Vincennes Bay, East Antarctica, is investigated based on five-time high-quality repeat hydrographic observations carried out in Januaries 2011-2015. Spatial and temporal variability in volumetric contribution of Vincennes Bay Bottom water (VBBW), the mixture of local Dense Shelf Water (DSW) and modified Circumpolar Deep Water (mCDW), to the AABW layer have been estimated respectively. Bottom water in this region is found having a significant freshening (0.0016 /yr on average) and minute warming (0.0002 °C/yr on average) trend during these years. Evidences show that VBBW has a freshening and cooling effect on the AABW layer. The largest contribution of VBBW (> 30 %) along the ridge northwestern of Vincennes Bay (VB) is accompanied by the freshest and coldest AABW property; VB-origin DSW freshens the internal layers of AABW, resulting in plume structures tending to fresher and cooler in the potential temperature-salinity diagram. Temporal variation reflects that there is a sharp increase of contribution of VBBW from 2014 to 2015 along 110°E. This variation corresponds well to the enhanced northward wind, larger upward heat flux and more sea ice formation in the coastal polynya region of VB during freezing season in 2014. Spatial contribution of VBBW, as well as DSW, indicates that the main outflow route of DSW may be along the ridge northwestern of VB. VBBW can reach the abyssal layer deeper than 4000 m at 61°S.

Trends of the deep water masses properties in the Bransfield Strait, Antarctica: Austral summers from 1960 to 2019

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The Bransfield Strait (BS) is influenced by dense Weddell Sea shelf waters recently ventilated. After sinking, these waters remain restricted in the BS deep basins due to their thermohaline properties and the bathymetric configurations. Thus, this region is frequently referenced to be a proxy area to study the temporal variability of the Weddell Sea shelf waters.Here, the temporal evolution of the water masses from the deep BS is investigated for the summer periods of 1960-2019. For this, historical hydrographic data from the Word Ocean Database 2013 and from Alfred Wegener Institute spanning from the 1960s to 2010s are combined with the High Latitude Oceanography Group (GOAL) measurements from 2003 to 2019. Cooling (–0.0021 ± 0.0020 ºC/yr), freshening (–0.0005 ± 0.0005 g kg^{-1} /yr) and lightening trends (–0.0011 ± 0.0010 kgm^{-3} /yr) are observed in the BS central basin for that period. In turn, the eastern basin shows warming (+0.0022 ± 0.0034 ºC/yr), freshening (–0.0007±0.0005 g Kg^{-1} /yr) and lightening (–0.0017 ± 0.0012 Kg m^{-3} / yr) for the same period. The results indicate a strong interannual variability of BS water masses thermohaline properties, which are related to changes in the wind patterns associated to the climate modes El Niño-Southern Oscillation and Southern Annular Mode. Periods of higher salinity are associated with increased intrusions of High Salinity Shelf Water from the Weddell Sea.

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Offshore Transport of Particulate Organic Carbon off the Antarctic Peninsula by Nonlinear Mesoscale Eddies

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The Southern Ocean plays a disproportionally large role in the global carbon cycle, accounting for a large fraction of the global ocean CO2 uptake. The Southern Ocean is also unique because it encircles the globe, providing a pathway for inter-basin exchange. Previous studies have shown that particulate organic carbon (POC) accumulates seasonally around Antarctica. Here, we examine the offshore export of POC off the Antarctic Peninsula, from areas of high accumulation near the coast to areas offshore that provide a link for exchange of water masses and biogeochemical properties between the worlds' major ocean basins. For that, we use decade-long satellite observations of POC based on algorithms validated against in situ data, eddy kinematic and propagation characteristics based on altimeter data and results from a high resolution ocean model coupled to a sea ice model. We show that mesoscale eddies are nonlinear (geostrophic velocities around the eddies exceed their propagation speed) in the top 750 m of the water column, and that cyclones located offshore that were generated near the coast contain higher carbon concentration in their interior than cyclones of the same amplitude generated offshore. This indicates that eddies are in fact trapping and transporting coastal water offshore. The offshore transport is estimated at 1.1 Sv off the Peninsula, resulting in an offshore POC enrichment of 4.5 ± 1.3 Gg/year. Eddies may also strongly influence the offshore transport of freshwater from ice melting, nutrients, phytoplankton and zooplankton, potentially creating offshore oases for higher trophic organisms.

1245

Italian mooring observations in the western Ross Sea from 1995 to 2019

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Antarctic Bottom Water (AABW) plays an important role in the deep ocean stratification and in the transport of heat, carbon and nutrients throughout the global ocean. In the Pacific Sector of the Southern Ocean, the Ross Sea is responsible for shaping the properties of approximately 25% of the world's AABW. The Italian Marine Observatory in the Ross Sea (MORSea) project, funded by the Italian National Program of Research in Antarctica (PNRA), has a network of four active moorings in the western Ross Sea: two located in the Terra Nova Bay polynya, where the HSSW precursor of the AABW is formed, and two close to the shelf break in the Drygalski and Joides troughs where the AABW is formed from the interaction of the shelf waters and the warm circumpolar deep water and subsequently exits from the continental shelf.
CTD data and moored observations time-series collected since 1995 have shown significant changes in the thermohaline characteristics of HSSW.
MORSEa mooring, deployed from 1998 to 2019 in the central Ross Sea, are demonstrating the important role played to assess the cross-shelf exchanges processes and changes in the AABW formation in the Ross Sea and how rapidly these changes occur.

1243

Characterization of the ocean mesoscale eddies in the Antarctic Circumpolar Current from in situ, model and remotely sensed data

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Mesoscale variability and associated eddy fluxes (EF) play crucial roles in the ocean dynamics. In the Southern Hemisphere, where the Antarctic Circumpolar Current (ACC) acts as a barrier to the direct heat transport toward the Antarctica, the EF across the ACC is the main mechanism that guarantees the heat budget and distributes physical and biogeochemical properties between subtropical and polar regions.
The study area is located between the South-West Indian and South Pacific ridges. In this area, the interaction between the ACC and the topography, produces large values of EKE and eddy heat fluxes and steers the ACC path.
The aim of this study is to evaluate the efficiency of mesoscale eddies to exchange heat and other properties across the different ACC fronts and to describe the vertical and horizontal properties of the eddies. To this end, we used in-situ and satellite data in conjunction with a hindcast simulation from 1958 to 2018 performed with a 1/10° ocean biogeochemistry model.
Eddies are identified and tracked in both the model output and altimetry data while their thermohaline properties and vertical extension in situ data as well, which include repeated XBT sections (i.e. New Zealand – Antarctica and Hobart – Antarctica) and Argo float profiles.
Thanks to the joint analysis of model and observational data, we are able to 1) assess the ability of the 1/10° ocean model of simulating the eddy field properties, and to 2) better interpret the spatial and temporal variability of the observed eddies

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Antarctic Bottom Water Outflow from the western Ross Sea: preliminary results from the Ross Sea Outflow Experiment

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Antarctic Bottom Water (AABW) sets the water properties of 40% of the global ocean and 25% of this water mass originates in the western Ross Sea. Recent and historic hydrographic and moored observations were used to investigate what controls the changes in water properties and outflow when dense plumes exit the shelf along the slope near Cape Adare in the Ross Sea. Bottom water exiting the region at Cape Adare is comprised of approximately 40% Ross Sea High Salinity Shelf Water (HSSW), 30% Circumpolar Deep Water (CDW) and 30% low-salinity AABW from further east. The seasonal cycle in salinity and temperature at Cape Adare can be explained by the seasonal cycle in salinity of HSSW in the Drygalski Trough. Dense water pulses occur twice a year, primarily in April and October, often after minimums in tidal velocities in both the semi-annual and spring-neap tidal cycles. Investigation continues on how tides and winds can modulate delivery of HSSW from the shelf to the deep ocean.

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Bottom water properties in the Australian-Antarctic Basin: A perspective from the Deep-Argo pilot array

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The production and export of Antarctic Bottom Water (AABW) regulates the global overturning circulation and ventilates the deep ocean. Roughly 40% of AABW is exported into the Australian Antarctic Basin after being formed in two distinct source regions near East Antarctica: Adelie Land and Ross Sea. Observations from the past several decades show both flavours of AABW freshening, with the highest rates of change near the bottom water sources. A pilot array of Deep-Argo floats capable of profiling to between 4000 and 6000 dbar (depending on float type) was deployed in early 2018 in the Australian Antarctic Basin that helps put the long-term changes in context with the spatial variability of properties in the basin. As of January 2020, 12 active floats in the region have recorded over 700 profiles, with almost 450 bottom-reaching profiles and almost 600 profiles reaching the top of the AABW layer (defined as γ > 28.3 kg/m3). Calibrated against quasi-contemporaneous shipboard CTD profiles, this array reveals absolute salinities and conservative temperatures spanning 0.03 and 0.3oC in the AABW layer, respectively, with larger property ranges in the bottom 100 m of the ocean. While Ross Sea sourced AABW is relatively warmer and more saline than that sourced from Adelie Land, the differences are compensated in density. This pilot array of Deep-Argo floats puts the observed changes over the past several decades into a broader spatial context and reveals pathways of AABW through the Australian Antarctic Basin.

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Anthropogenic temperature and salinity changes in the Southern Ocean

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The Southern Ocean is an essential part of the climate system, due to its disproportionately-important role in global heat and carbon uptake. Hence, changes in its physical properties, especially those that affect water mass transformations (temperature and salinity) have global implications. In this study, we perform a multi-model attribution of the primary forcings of historically-observed Southern Ocean temperature and salinity change, from 1966-2005. Consistent with previous research, we find a robustly-detectable anthropogenic greenhouse gas (GHG) response, characterized most clearly by a warming of Sub-Antarctic Mode Waters and a freshening of Antarctic Intermediate Waters. The warming pattern is somewhat mitigated by non-GHG anthropogenic forcings (i.e. anthropogenic aerosols or stratospheric ozone depletion). We also find evidence of a detectable GHG-forced change in denser watermasses (i.e. deeper than 2000m and south of 60oS), with a warming of Circumpolar Deep Water and warming and freshening of Antarctic Bottom Water; the latter result must be considered with caution given the poor representation of Bottom Water in climate models.

1434

Thermal responses to Antarctic ice shelf melt in an eddy rich global ocean–sea-ice model

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Water-mass exchange across the Antarctic shelf margin plays a crucial role in abyssal ocean ventilation and the transport of ocean heat to Antarctic glaciers. Coastal freshening from accelerating Antarctic land-ice melt may alter dynamics at the shelf margin, with implications for deep ocean heat storage and future ice shelf melt rates. Due to the scarcity of observations near the Antarctic coast and difficulties associated with resolving high latitude processes in ocean models, such responses are poorly constrained and confer large uncertainties to projections of future sea level.

Using a high resolution (0.1°) global ocean–sea-ice model with a realistic representation of near-Antarctic water mass properties, we investigate the response of near-Antarctic waters to increased meltwater. We conduct two freshwater perturbation experiments based on projected ice-loss rates under RCP 4.5 and RCP 8.5 emissions scenarios at 2100. Within 10 years of the puerturbation, formation of Dense Shelf Water ceases. On the shelf, increased ocean stratification in Dense Shelf Water formation regions leads to subsurface warming, suggesting a positive feedback to ice shelf melt in these regions. In other regions, coastal freshening strengthens the Antarctic Slope Front, inhibiting the transport of warm Circumpolar Deep Water onto the shelf. Thus, freshening isolates cool shelf waters from open ocean heat, indicating a negative feedback to ice melt, and homogenize shelf waters, enhancing remote feedbacks. The net effect over the continental shelf is cooling, comprised of strong positive and negative regional temperature responses with complex implications for future melt rates.

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The neodymium isotope fingerprint of Ross Sea Bottom Water

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Unlocking the interplay between ocean circulation and climate change remains a key target in paleoceanography and palaeoclimate research. The 143Nd/144Nd ratio of seawater, expressed as εNd, is commonly used as a tracer for reconstructing the provenance of water masses. Applications so far have mainly focussed on the North Atlantic. What is less explored is the εNd fingerprint of Antarctic Bottom Water (AABW), now and in the past.

We here present new dissolved Nd isotope and concentration results from 15 seawater samples collected at 9 stations on the 2018 GO-SHIP cruise SO4-P around the Ross Sea. This area produces ~25% of modern AABW, and exports two physically different varieties of Ross Sea Bottom Water (RSBW). Results for both varieties of RSBW display a homogenous Nd isotopic composition of εNd = -7.3 ⍰ 0.2 (2 S.D., n = 6) and Nd concentrations of 24.13 ⍰ 0.03 pmol/kg (2 S.D., n = 6).

This Nd isotope signature of RSBW is distinct from Weddell Sea Bottom Water (εNd = -9.0 ± 0.8), Adelie Land Bottom Water (εNd = -8.9 ± 1.0) and local overlying Circumpolar Deep Water (εNd = -8.3 ± 0.7). In order to explore how RSBW acquires its unique Nd isotopic composition we will compare the influence of precursor water mass mixing on the shelf, and ‘bottom-up’ sediment-seawater exchange processes as inferred from detrital Nd isotope signatures. Determining which process exerts the stronger influence on the Nd isotopic composition of RSBW is critical for interpreting past Nd isotope variations in paleoceanographic records.

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Hotspot of carbon fluxes along the Polar Front

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The Southern Ocean is an important contributor to the global carbon sink and is of most importance for our global climate. The capacity of the ocean to store and sequester carbon is set by the ocean circulation which transfers carbon in and out of the deep ocean. Decadal variability in the southern ocean carbon sink has been linked with variability in the large-scale upwelling of old carbon- and nutrient-rich deep water, the Circumpolar Deep Water (CDW).
While we know that outcropping of CDW results in CO2 outgassing, especially near the Antarctic continent, lots is still to learn about the CDW pathways from the ocean interior to the surface. Here we highlight an efficient pathway for CDW surfacing. We found that at the crossing of oceanic ridges, hotspots of carbon outgassing are a signature of CDW outcropping. We use a biogeochemical eddy-resolving ocean simulations (1/10°) to investigate the physical mechanisms involved in the CDW outcropping and carbon outgassing at these hotspots. We show that upwelling induced by flow-topography interaction, fronts merging and baroclinic instabilities control local CDW pathways resulting in hotspots of CO2 outgassing.
Gaining in-depth process understanding can help reducing uncertainties in the net contribution of the southern ocean to the global carbon sink.

1610

Frontal variability of the Antarctic Circumpolar Current.

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The Antarctic Circumpolar Current (ACC) plays a major role in regulating the transport of heat between the lower latitudes and Antarctica. The ACC has multiple substructures and fronts. Over the last decades, several studies have investigated the variability and shifts of these fronts with variable answers. Here we use 26 years of Satellite altimetry and 15 years of Argo sampling to monitor the changes in the ACC and interpret them at the same time as investigating the effect of methods used to monitor these fronts. One main finding is that the global sea level rise can significantly impact the results. Some studies reported large southward shifts of the fronts by using reference dynamic topographic levels as proxy to frontal position. Here we show that this is not as simple and that the large scale sea level rise needs to be taken into account. We propose a method to account for the large scale sea level rise in frontal position monitoring.

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Separating roles of individual air-sea fluxes in the Southern Ocean warming under anthropogenic climate change

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The Southern Ocean is one of the key regions absorbing the excess heat stored in the climate system due to anthropogenic warming. It remains unclear how changes in the heat and freshwater fluxes and the poleward intensification of the westerly winds play different roles in driving the Southern Ocean warming patterns and magnitudes. In this study the contributions from individual air-sea fluxes are separated using global ocean model perturbation experiments, forced by the wind stress, heat flux, and freshwater flux anomalies under the doubled CO2 concentration provided by the Flux-Anomaly-Forced Model Intercomparison Project (FAFMIP). Several key findings include: (1) The surface heat flux changes account for most of the ocean warming by adding heat into the ocean which is in turn redistributed by the background ocean circulation; (2) the wind-driven heat convergence is the key to enhance the deep-reaching warming at middle latitudes (centred at ~45ºS); (3) The poleward expansion of the subtropical gyres is primarily attributed to the wind forcing and heat accumulation near the poleward edges of the subtropical gyres. The wind forcing also drives a clockwise shift of the isopycnals in the Southern Ocean indicating a spin-up of the meridional overturning circulation (MOC) and the Antarctic Circumpolar Current (ACC); (4) The surface heat flux changes dominate the spiciness changes along density surfaces including cooling and freshening within the Subantarctic Mode Water (SAMW) and the Antarctic Intermediate Water (AAIW), whereas the surface freshwater flux changes contribute to a lesser extent.

1510

Changing water masses and their mechanisms in a standing meander in the Antarctic Circumpolar Current

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Most theories of the Southern Ocean and more specifically the Antarctic Circumpolar Current are based on zonally symmetric models that lack information about the complexity of the frontal structure and the presence of several significant topographic obstructions that cause the flow to meander.

We surveyed a standing meander in the Subantarctic Front downstream of the Southeast Indian Ridge with 11 cross-frontal transects, comprising 99 CTD profiles to ~1500 dbar, to examine the along stream change of watermass properties in the upper ocean. We describe the change in properties relative to gravest empirical mode reference fields of temperature and salinity.

Our results show that most of the temperature changes are on density levels rather than due to the vertical displacement of density layers. In the intermediate and upper deep waters ($\gamma n > 27.2$), temperature anomalies change from cold to warm from trough to crest. Whereas, in the mode waters ($26.8 < \gamma n < 27.2$) the temperature anomalies change from warmer into the trough to progressively colder in between trough and crest and then warmer into the crest again. The discrepancy between the upper and lower water column suggests different mechanisms at work.

Standing meanders from our results seem to be important pathways in heat transport as most of the watermass changes occurs on isopycnals. In the upper water column, the watermass changes occur due to changes in kinematics, whereas in the lower water column watermass changes are due to the turning of the velocity vector with depth inside standing meanders.

1438

Heat transport towards Antarctica driven by local dense water export in canyons

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Poleward transport of warm Circumpolar Deep Water (CDW) has been linked to melting of Antarctic ice shelves. However, even the steady state spatial distribution and mechanisms of CDW transport remain poorly understood. Using a global, eddying ocean model, we explore the relationship between CDW transport across the continental slope and descending Dense Shelf Water (DSW) transport. We find large spatial variability in onshore CDW heat and volume transport around Antarctica, with significantly enhanced flow where DSW descends in canyons. The CDW and DSW transports are highly spatially correlated within ~20km and temporally correlated on sub-daily timescales. Focusing on the Ross Sea, we show that the relationship is driven by pulses of overflowing DSW lowering sea surface height, leading to net onshore transport of CDW. The majority of simulated onshore CDW transport is concentrated in cold-water regions, rather than warm-water regions, with potential implications for ice-ocean interactions and global sea-level rise.

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Indian Scientific Expeditions to Southern Ocean an overview and future perspectives

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The Southern Ocean is a very remotely accessible region due to its harsh climatic conditions, however it strongly controls the global climate. National Centre for Polar and Ocean Research has implemented eleven multi-disciplinary, multi- institutional scientific expeditions in the least investigated Indian sector of Southern Ocean since 2004 under the aegis of Ministry of Earth Sciences, Govt. of India. Comprehensive synoptic and time series observations are being made from these expeditions. The main focus is the "Role and response of Southern Ocean in the global and regional climatic variabilities". Studies are being undertaken to understand the air-sea-ice interaction, role of anthropogenic aerosols, water masses, circulation, biogeochemistry, productivity, carbon sequestration and paleoclimate. The major outcomes include- zones of sink (52°S) and ventilation (45°S) of CO_2; southward meandering of Antarctic Circumpolar Current; fast rate warming and freshening of bottom water; eddy influenced water masses movements; dominance of non sea salt aerosols; enhanced productivity in the shallow subtropical region; influence of melt water on productivity in the coastal and open ocean. Although changes are observed in the air-sea fluxes, hydrography and biophysical processes the data is not enough to predict the behaviour of the region in a rapidly changing climate scenario and it's influence on tropical climate variability. The future research in these waters will therefore largely focus on acquiring continuous data that involve long-term continuous observations using remotely operated platforms including moorings, floats, gliders etc.

Key words: Southern Ocean, hydrodynamics, biogeochemistry, water masses, eddies

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The Southern Ocean Observing System: Supporting the Community with Networks and Tools

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The Southern Ocean Observing System (SOOS) is an initiative of SCAR and SCOR and has the mission to enhance the collection and delivery of Southern Ocean observations to researchers and the broader community. SOOS was developed to address critical gaps in our observations of the Southern Ocean, which have led to uncertainties in estimates of the future state of Southern Ocean processes and the subsequent global consequences.

SOOS has now been operating for 9 years, and during this time has built community networks, focussed task groups, and tools to support collaboration and data discovery – towards addressing key observational gaps. This presentation will provide an overview of the achievements of SOOS over the last 5 years; highlight the ways that SOOS can support you in your research and data objectives; and outline the key priorities for SOOS over the next 5 years.

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Surface water fCO_2 and Sea-Air CO_2 flux variability across the Weddell gyre and eastern sector of the Atlantic Southern Ocean, offshore Droning Maud Land/Hakon VII hav for Fall Season 2019

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Unique austral autumn sea surface water CO_2 was monitored between 28th of February and 10th of April 2019 from Punta Arenas across the Weddell gyre and the eastern sector of the Atlantic Southern Ocean. The relative roles of the physical, chemical and biological drivers controlling the surface ocean CO_2 dynamics in the Antarctic circumpolar current (ACC) and Weddell gyre were elucidated by a correlation of CO_2 saturation (fCO_2_sat) to O_2 saturation. Surface property-property relationship of sea surface temperature (SST), sea surface salinity (SSS) and chlorophyll a (chl a) with fCO_2_sat suggests that the ACC is a weak CO_2 sink in autumn with -2.85 (±2) mmol/m²/d and -1.58 (±3) mmol/m²/d average CO_2 uptake across the west and eastern ACC transect respectively. The uptake observed in the ACC were influenced by hydrographic fronts in the ACC and photosynthesis. Frontal positions were identified by our hydrographic data and variation in the sea surface CO_2 distribution was observed at the frontal positions. A larger CO_2 flux (-8.85 (±10) mmol/m²/d) was computed for the Weddell gyre. Although, an intense CO_2 source was identified south of 60^oS due to combined upwelling of CO_2-rich waters and organic matter remineralization, the larger uptake is attributed to cooling and the photosynthesis occurring in the upwelling area of Maud Rise. An austral autumn mean CO_2 flux of -2.52 mmol/m²/d determined previously for the entire Weddell gyre compared with this study indicates the increasing CO_2 sink capacity of the Weddell gyre in autumn.

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Role of Southern Ocean eddies in cross-frontal transport of physical and biogeochemical properties

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Mesoscale eddies are rotating bodies of water with diameters between 10 and 100 km that live from weeks to months. They are known to carry heat, salt and nutrients across Antarctic Circumpolar Current fronts, thereby playing a key role in the global meridional overturning circulation. Limited direct observations make it difficult to quantify the actual amount of heat, salt and nutrients carried by discrete eddies. Here, we present new observations of a cold-core eddy, collected during a voyage in the Subantarctic Zone south of Tasmania. Our analysis indicated that the amount of heat and salt carried into the Subantarctic Zone by cold-core eddies is much larger (~ 3 times) than previously reported. We also provide the first estimate of the nutrient content of the eddy and demonstrate that it carries a surplus of nitrate and a deficit of silicate relative to Subantarctic Zone waters.

Based on our ship-based observations in conjunction with satellite measurements of sea surface height and an eddy-tracking software, we propose that about 20% of the heat carried across the Subantarctic Front south of Tasmania is achieved by long-lived cold-core eddies entering the Subantarctic Zone. The annual volume of freshwater carried into the Subantarctic Zone is of the same order of magnitude as that delivered by equatorward Ekman transport. In terms of nutrients and carbon, we hypothesise that long-lived cold-core eddies can increases subantarctic mode water nutrient contents by up to 27%, which in turn has implications for global productivity and ocean carbon uptake.

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Flood gates for heat to Antarctica: observations in an Antarctic Circumpolar Current standing meander

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The interaction of the Antarctic Circumpolar Current with steep topography generates standing meanders in the flow. Such meanders are hot spots for eddy generation and poleward transfer of heat and other properties. Model studies and theoretical work suggest these meanders also play a significant role in dissipating the momentum imparted by strengthening westerly winds, preventing an acceleration of the ACC.

Observations in a standing meander of the Polar Front southeast of Tasmania were gathered to examine the evolution of watermass and velocity structure along the meander, and cross-stream fluxes, over the full water column. The suite of observations included full depth hydrographic transects with microstructure and biogeochemistry, high-resolution towed body measurements to 300 m, surface drifters and EM-APEX profiling floats. A heavily-instrumented tall mooring recorded an 18-month time series of water property variations and cross-stream fluxes at the crest of the meander.

The focus of this talk are the EM-APEX data which recorded watermass and velocity changes through a transition from parallel shear flow upstream of the Polar Front meander, to chaotic pathways through an intense eddy field within the meander trough. They were eventually ejected from the trough and followed a smooth pathway eastward and northward along the western side of the Macquarie Ridge to pass through a narrow gap in the ridge. We describe the along-stream variability and discuss the implications for cross-frontal exchange.

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Antarctic shelf water changes in CMIP6 models

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Antarctic shelf water plays a crucial role in driving global climate. Shelf water influences Antarctic ice sheet mass loss by ice shelf basal melt, and the formation of dense water in shelf regions modulates the global Meridional Overturning Circulation. Observational analyses have identified a shelf water warming in the Amundsen and Bellingshausen Seas, linked to a shoaling of Circumpolar Deep Water over the continental slope (Schmidtko et al. 2014). Here, we analyse temperature and salinity from the Coupled Model Intercomparison Project phase 6 (CMIP6). We assess the historical mean state and recent decadal changes in Antarctic Continental Shelf Bottom Water, Circumpolar Deep Water and Winter Water, and compare them to observed changes. We also assess projected changes under the high radiative forcing scenario (SSP5-8.5). Regions of the strongest simulated trends are compared with observed, and we identify regions of projected ice shelf melt sensitivity around Antarctica.

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There goes the neighbourhood: how enhanced ice shelf melting is impacting downstream polynyas in East Antarctica?

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Antarctic Bottom Water (AABW) production, critical to the global overturning circulation, will be negatively impacted by a freshening of dense shelf waters by enhanced ice shelf melting. Using elephant seal data, we have investigated the relationship of glacier melt and downstream polynyas in East Antarctica that have been found to produce dense shelf water: Cape Darnley/Prydz Bay and, most recently, Vincennes Bay. The dense Cape Darnley source is currently on balance, protected by the recirculation of melting water within the Prydz Bay Gyre. The Vincennes Bay source is considered the weakest, producing a lower density shelf water that ultimately only contributes to the upper later of offshore Bottom Water. However this increases its significance, as a potential example of an AABW source region that could shutdown in response to ongoing and future change. Providing the first detailed oceanography description of the region, we found extraordinary intrusions of bottom-intensified modified Circumpolar Deep Water during late summer/early fall that is bottom-intensified by the influence of fresh meltwater-laden Winter Water from the upstream Totten Glacier. Local ice-shelf melting is likely to be occurring, as Vincennes Bay is fresher than surrounding waters. There is a complex interaction of mCDW with dense shelf water formation beneath two polynya regions, as the heat flux reduces local sea ice growth but the mCDW provides a positive salinity flux. Into the future, Vincennes Bay will be an important site to monitor the influence of enhanced ice sheet melting on East AABW.

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Recovery of Ross Sea Bottom Water formation driven by anomalous climate forcing

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Antarctic Bottom Water (AABW) supplies the lower limb of the global overturning circulation, ventilates the abyssal ocean, and sequesters heat and carbon on multidecadal to millennial timescales. AABW is supplied by dense water formed on the Antarctic continental shelf by strong winter cooling and brine released during sea ice formation. Over the past 50 years, the salinity, density and volume of AABW has decreased, with the most dramatic changes observed in the Ross Sea Bottom Water (RSBW). These changes have been attributed to increased melting of the Antarctic Ice Sheet. Here we use new observations to document a recovery in the salinity, density and thickness of RSBW, with properties in 2018-2019 similar to those observed in the 1990s. The recovery is the result of increased sea ice formation on the continental shelf. The increase in sea ice formation was triggered by anomalous wind forcing associated with the unusual combination of positive Southern Annular Mode and extreme El Niño conditions between 2015 and 2018. Our study highlights the sensitivity of bottom water formation to remote forcing and shows that episodic increases in sea ice formation driven by climate anomalies can counter the tendency for increased ice sheet melt to reduce AABW formation.

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Decadal trend of the carbonate system properties of shelf waters and of Antarctic Bottom Waters in the Ross Sea (Antarctica)

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Ross Sea Bottom Water (RSBW), the second largest source of Antarctic Bottom Water (AABW), is formed by the mixing of the Dense Shelf Water (DSW) and Circumpolar Deep Water (CDW) along the continental slope. Changes in the thermohaline properties or in the volume of the sinking dense waters can result in changes in chemical properties, such as the amount of anthropogenic CO_2 (Cant) injected in the deep layers. Total alkalinity (AT) and pH samples collected during 5 Italian Antarctic Research Program (PNRA) expeditions between 2006 and 2017 were analyzed to evaluate the variability of the carbonate system associated with different water masses in the Ross Sea. The water masses on the Ross Sea continental shelf were identified trough their physical and chemical data. The results allow to evaluate the carbonate system variability on a ten-year scale, which is considered representative for this area, considering the increase of global atmospheric CO_2 from 382 to 405 ppm and the interannual variability of the basin. The Cant values obtained from the application of TrOCA method to the dataset vary over the years between 9 and 61 µmol/Kg on average, emphasizing that the deep layers of the water column are invaded by anthropogenic carbon. The highest concentrations are found associated with the presence of High Salinity Shelf Water (HSSW) in the Terra Nova Bay polynya area, where this water mass is formed during winter. The observed variability suggests that future climatic changes may significantly affect carbon cycling in this dynamic environment.

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Control of the oceanic heat content of the Dotson Trough, Antarctica, by the Amundsen Sea Low

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The supply of warm Circumpolar Deep Water (CDW) to the West Antarctic continental shelf is responsible for the basal melting and thinning of the West Antarctic ice shelves that has occurred in recent decades. Here, we assess the variability in CDW supply, and its drivers, from a multi-year mooring deployed in, and a regional ocean model spanning, the Dotson Trough, Amundsen Sea. Between 2010 to 2015, the CDW within the trough underwent a pronounced cooling and freshening, associated with changes in thermohaline properties on isopycnals. Variability in the rate of CDW inflow is tightly controlled by local wind forcing of a shelf-break undercurrent, which determines the hydrographic properties of inflowing CDW via tilting of density surfaces above the continental slope. Local wind forcing is coupled to the Amundsen Sea Low (ASL) low-pressure system, which is modulated by large-scale climatic modes via atmospheric teleconnections. For the period analysed, a deeper ASL was associated with westward wind anomaly at the shelf-break. Changes in the sea surface slope decelerated the shelf-break undercurrent, resulting in less heat accessing the continental shelf and, consequently, a cooling of the Dotson Trough. As well as regulating the delivery of CDW toward the Amundsen Sea, the ASL influences the westward export of meltwater from the region via changes in the intensity of a coastal current, with possible consequences for the freshening of the Ross Sea.

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A hydrographic gridded data set for the Northern Antarctic Peninsula

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The Northern Antarctic Peninsula (NAP), is characterized as a transitional oceanic regime composed by warmer and saltier waters originated from the Bellingshausen Sea and colder and relatively fresher shelf waters from the Weddell Sea. This dichotomy provides an intense oceanographic variability on interannual time-scales. On longer time-scales, its deep waters, which are fed mainly by Weddell Sea shelf waters, have shown freshening and lightening trends. Due to its relatively easy access, the NAP can be considered an in situ laboratory to study changes associated with the Weddell Sea shelf waters. The Brazilian High Latitude Oceanographic Group (GOAL) has been surveying the region quasi-annually since 2003, measuring high-resolution hydrographic profiles. Here, we make use of this rich database from 2003 to 2019 to create a high-resolution gridded product for the NAP. Profiles of temperature, salinity and dissolved oxygen were linearly interpolated into 114 vertical levels between 5-4500 m. Then, the profiles were optimally interpolated into a grid of ~10 km resolution in space. The gridded product successfully captures the main water masses present in the region, the regional fronts (e.g. Peninsula Front and the Bransfield Front) on the surface and on deeper depths, as well as the intrusion paths of the water from Bellingshausen and Weddell Seas. As an example of its potential use, we highlight the validation of regional models, and to provide direct estimates of transport into and out of the NAP and its straits. Once ready, the NAP high-resolution gridded product will be freely available.

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Bi-stability of the Filchner-Ronne Ice Shelf Cavity Circulation and Basal Melt Rates

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Circulation and water mass transformation within the Filchner-Ronne Ice Shelf (FRIS) cavity create precursors to Antarctic bottom water, which closes the global overturning circulation. This water mass transformation is contingent upon a relative low rate of FRIS basal melt, currently around 100-200 Gt/yr. Previous studies have indicated that Antarctic climate changes may induce intrusions of warm modified Warm Deep Water (mWDW) and an order-of-magnitude increase in basal melt, and signatures of mWDW have recently been observed along the face of the FRIS. However, it remains unclear how changes in near-Antarctic climate translate mechanistically to changes in mWDW access to the FRIS cavity.

In this study a regional model is developed to investigate FRIS circulation dependence on local atmospheric state. Experiments with modified initial cavity conditions but identical atmospheric states yield bi-stable ``warm'' and ``cold'' FRIS cavity states, with an order-of-magnitude difference in basal melt rates. Idealized atmospheric perturbation experiments reveal that relatively modest perturbations to the katabatic winds shift the FRIS cavity between ``warm'' and ``cold'' states, which occur when the FRIS cavity is filled by mWDW or High Salinity Shelf Water (HSSW), respectively. The authors present a conceptual model in which the FRIS cavity state is determined by whether mWDW or HSSW is denser, and thus floods the cavity; these states are bi-stable because the basal melt rate feeds back on the salinity of HSSW. These findings highlight a key role for the katabatic winds in mediating the melt of the FRIS and other Antarctic ice shelves.

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Effect of resolution on heat and carbon dynamics in a regional ocean circulation model for the Argentine Basin

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The Argentine Basin is a region of strong currents and turbulent mixing of subpolar and subtropical waters, with large uncertainties surrounding integrated quantities such as air-sea exchanges of heat and carbon. We construct a regional ocean model with biogeochemistry at 1/3, 1/6, and 1/12 degree resolutions for the year 2017 and use initial conditions and boundary forcing from BSOSE (the Biogeochemical Southern Ocean State Estimate) and atmospheric forcing from ERA5. Model output is compared against Argo and SOCCOM float profiles, sea surface height maps, and other observation-based products. We quantify the effect of resolution both on misfit to these products, on model upper ocean heat and carbon content and the associated air-sea exchanges, and vertical transport in the upper ocean.

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Lagrangian pathways and residence time of warm Circumpolar Deep Water on the Antarctic continental shelf

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The inflow of relatively warm modified Circumpolar Deep Water (CDW) onto the Antarctic Continental Shelf and into ice shelf cavities is a key driver of Antarctic ice shelf mass loss. While there have been recent advances in understanding the processes that control the rate of CDW transport onto the continental shelf in different regions around Antarctic, there is a gap in understanding the fate and residence time of the CDW on the shelf. Here we use Lagrangian particle tracking experiments in a high resolution circum-Antarctic ocean-ice model to map both the pathways and residence times of CDW on the Antarctic continental shelf. We investigate how residence times and transformation of CDW vary by region along the continental shelf. Results show complex spatial heterogeneity in residence times of CDW in the shelf, with generally shorter residence times in regions of rapid water mass transformation on the shelf and much longer residence times elsewhere. These results emphasize that it is the residual of the heat transport of CDW onto the shelf and the transformation into denser waters on the shelf, rather than the heat transport of CDW onto the shelf alone, that is relevant for the reservoir of warm waters on the shelf available to for ice shelf melt.

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Combined glider and float observations of Southern Ocean ventilation at submesoscales

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Characterized by weak stratification, energetic frontal currents, and strong surface forcing, the Southern Ocean is susceptible to submesoscale instabilities that influence vertical tracer transport, air-sea exchange, and mixed layer depths. Here we present observations from two separate ocean glider deployments focused on transitions in ventilation and water mass transformation across the Polar Front.

In the ChinStrAP2 project, two ocean gliders were piloted across the Polar Front (PF) in Drake Passage. Despite strong surface wind and buoyancy forcing, a meltwater lens south of the PF suppresses small-scale variability and subduction in the upper ocean. Surface-interior exchange is instead localized to the PF. The intensity of upper ocean ventilation and lateral mixing at the PF increases in response to a deepening of the surface mixed layer and a weakening of the front during mid-winter, which enables along-isopycnal subduction of surface waters into the interior. During the SOGOS project, two ocean gliders were deployed alongside a SOCCOM semi-Lagrangian biogeochemical float near the PF in a large standing meander in the Indian sector of the Southern Ocean. Comparisons of physical properties and tracer variance between the high-strain/EKE region and the low-strain/EKE downstream region underscore the importance of vigorous eddies in the production of deep-reaching lateral buoyancy gradients which can lead to vertical transport via cross-frontal secondary ageostrophic circulation. Optical backscatter measurements suggest links between particular export and small-scale circulation features. We conclude that submesoscale have a strong impact on exchange between the surface boundary layer and the interior in the Southern Ocean.

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21st century projected sea surface temperature in the Southern Ocean and the potential impacts on microbial diversity

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Anthropogenic global warming can have devastating impacts on marine ecosystems, especially on climate-sensitive regions such as the Southern Ocean (SO). It is, therefore, critical to understanding how Sea Surface Temperature (SST) may change in the future since it is one of the most pressing aspects of climate change with blunt consequences for Antarctic pelagic microbiomes. As key drivers of biogeochemical cycles, estimating microbial diversity and community structure across temperature will allow us to predict ecosystem functioning and help delineate potential interactions and niche characteristics. By using a suite of numerical tools derived from physical oceanography, machine learning, and microbial ecology, we investigate the long-term changes in the SO's SST throughout the 21st century, as projected by CMIP6 Earth System Models simulations, as well as the microbial diversity and interactions responding to temperature in the northwestern Antarctic Peninsula, which is rapidly warming. Four Shared Socioeconomic Pathways (SSPs) ranging from the mitigation and adaptation to the high emissions scenarios (i.e., SSP126, SSP245, SSP370, and SSP585) are considered to assess the SO's surface sensitivity to a warming climate. We discuss the potential impacts of these projections on Antarctica's marine diversity of bacteria and archaea, which are expected to be significant and persistent by the late 21st century, especially within the higher end of the range of future forcing pathways.

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A Three-Dimensional Analysis of the Southern Ocean Residual Circulation

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The Southern Ocean has a major role in the global air-sea carbon fluxes, with some estimates suggesting it takes up 40% of anthropogenic carbon dioxide. Understanding the Southern Ocean residual overturning is particularly important because it fluxes tracers between the depth and the surface. The Southern Ocean is faced with a changing climate and changing winds, but there is little theory to describe how the residual overturning in a Southern Ocean-like channel will respond to changes in wind when there is a blocking ridge, or how the existence of the ridge changes the circulation. This study uses a re-entrant MITgcm channel to examine how residual overturning, generated by appropriate relaxation boundary conditions, varies with the wind. An analysis of the three-dimensional residual circulation highlights the localized nature of this transport and the non-linear response of the circulation to changes in wind. The localization of the vertical flow shows the necessity of highly focused observations in the Southern Ocean to understand the transport.

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SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 8

PAST TO FUTURE INTERPLAY BETWEEN ICE SHEETS IN THE WORLD AND REGIONAL TO GLOBAL TELECONNECTIONS

Florence Colleoni
Suchithra Sundaram, Sunghan Kim, Ian Goodwin
Co-Convened with the IASC Cryosphere Working Group (Guðfinna Th Aðalgeirsdóttir)

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Australian-Antarctic rift-drift transition and development of the Antarctic Circumpolar Current – new IODP drilling in the Australian-Antarctic abyssal plain

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Despite many efforts, fundamental questions remain about the timing of onset, steps in development and attainment of present-day vigour of the Antarctic Circumpolar Current (ACC). Tectonic Australian-Antarctic (AA) separation played a critical role in this development, but the true nature of this tectonic opening remains elusive: timing of and mechanisms during the rift-drift transition, as well as post-rift subsidence history, are poorly constrained by the available sedimentary archives. The development of the ACC during subsequent seafloor spreading is poorly documented. We here present a pre-proposal for IODP to drill and collect the unique rock archive recording the onset and nature of ocean crust formation, and sedimentary archives across the core of the flow path of the ACC, where it is unobstructed by geographical boundaries. Through this, our drilling proposal innovatively connects structural geologic/geophysical objectives with paleoclimate/paleoceanographic objectives. We also present expedition plans to survey the AA abyssal plain sedimentation processes under influence of both ACC and Antarctic bottom water flow. In our drilling plans, one site from the Australian continental rise/abyssal plain transition will recover peridotite ridge/basement rocks and portray the overlying sedimentary conditions reflecting post-rift subsidence. A site on the Antarctic continental rise will reveal the subsidence history conjugate to the Australian margin. Two sites on the AA abyssal plain will represent the Cenozoic evolution of the ACC flow. All four sites combined will complete the latitudinal transect of sediments necessary to reconstruct the evolution of latitudinal sea surface temperature gradients, a keystone feature of the present-day vigorous ACC.

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Oceanographic and temperature consequences of tectonic opening of the Tasmanian Gateway

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Over the course of the Cenozoic (66-0 Ma), tectonic rift between Australia and Antarctica opened and progressively widened the Tasmanian Gateway. The regional oceanographic consequences and therefore the role of Tasmanian Gateway changes in the onset of Eocene cooling, Antarctic glaciation and proliferation of sea ice, and the development of a modern-day-like Southern Ocean oceanography are poorly resolved. Through various research projects over the past years, we have generated quantitative temperature reconstructions (sea surface and land temperature, based on fossil lipid biomarkers), from biomarker data, combined with dinoflagellate cyst assemblages, to reconstruct the paleoceanographic conditions around the Tasmanian Gateway. We generated data from ODP Site 1172 in the Southwest Pacific Ocean (Maastrichtian- Oligocene), ODP Site 1170 (South Tasman Rise; Middle and Late Eocene), ODP Site 1168 (west Tasman margin; late Eocene-recent), The Otway Basin (southern Australia; late Paleocene - early Eocene), DSDP Site 274 (offshore Cape Adare; Oligocene-early Miocene) and IODP Site U1356 (Wilkes Land Margin; Eocene-Miocene). We recognize the surprisingly similar temperature conditions on either side of the Tasmanian Gateway prior to opening (ca. 50 Ma), during the Paleocene and Eocene, a progressive cooling on both sides as the gateway first opens during the early Eocene and still warm ice-proximal conditions during the Oligocene and Miocene. A progressive development of the SST gradients and modern-like frontal systems is found from the late Miocene onwards. Collectively, our records provide a comprehensive overview of the oceanographic and climatological consequences of the opening of the Tasmanian Gateway.

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Comparison of high-latitude interannual variability of the Northern and Southern Hemispheres during the last glacial-interglacial transition.

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A preliminary high-resolution water isotope record has recently been recovered from the East Greenland Ice Core Project (EGRIP). This record is currently dated to 15 ka but additional work will allow a depth age scale through about DO event 12 (50+ ka). There also exists a 5 cm resolution NGRIP (North Greenland Ice Core Project) water isotope record for high resolution comparison. Using these records, we will determine how interannual and decadal variability changed across the last glacial-interglacial transition. Previous research from the WAIS (West Antarctic Ice Sheet) ice core revealed a 50% reduction in the amplitude of interannual variability after 16 ka, due to climate dynamics of the tropical Pacific and ultimately the topography of the Laurentide ice sheet. This finding was remarkable in that the large northern ice sheets greatly affected southern hemisphere climate. Did a similar shift in high frequency climate variability also occur in Greenland, which was much closer to the Laurentide ice sheet? We'll explore this possibility using the EGRIP and NGRIP records, and make comparisons with a new record from South Pole (east Antarctica) and the existing WAIS record. We hypothesize that a different signal will be present at these Greenlandic sites because north Atlantic climate variability is driven by substantially different climate dynamics than those in the Pacific. Ultimately, we will test our results using global circulation models and present the most up to date results at this conference.

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Inter-annual variability of Antarctic Sea Ice Extent and Indian Summer Monsoon Rainfall

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Teleconnection between the variability of the Antarctic Sea Ice Extent (AnSIE) and the tropical climate has been extensively investigated. The study examines the interannual relationship between the variability of sea ice extent in the Indian Ocean (SIEIO) sector (20º–90ºE) and Indian summer monsoon rainfall (ISMR) under the influence of the Mascarene High (MH). SIEIO in high (HIP) and low (LIP) ice phase years during April-May-June (AMJ) appeared to have a significant correlation to ISMR in the Peninsula India region during June-July-August-September (JJAS), with correlation coefficients of 0.51 and 0.71, respectively. Composites of mean sea level pressure (MSLP), 500 hPa geopotential height, and 850 hPa wind anomalies during HIP and LIP also showed that there was a relationship between the SIEIO and the MH, revealing that HIP and LIP correspond respectively to the strengthening and weakening of the MH as well as increases/decreases in ISMR. During the respective HIP and LIP years, positive and negative MSLP anomalies were found respectively, particularly over the MH region associated with the eastwards and westwards shifts of its center from the normal locations. Similar features were also observed at 500 hPa geopotential height anomalies. In addition, 850 hPa wind flow illustrated strong anti-cyclonic and cyclonic anomalies in the MH region, which lead to corresponding strong and weak southwesterlies and thus respective positive and negative ISMR anomalies. Hence, a positive MH anomaly was associated with more ISMR

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Can we improve the reconstructions of Antarctic snow accumulation over the last centuries by using climate information from outside Antarctica?

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Reconstructing the Antarctic climate over the last centuries is challenging because the number of records (mostly composed of ice core records) is low and they are unevenly distributed over the continent. However, numerous studies have shown strong teleconnections between the Antarctic climate and the climate at higher latitudes of the Southern Hemisphere. Those regions offer a larger and a more varied climate proxy network than Antarctica, in particular tree ring widths. Here, we aim to constrain the drivers of Antarctic snow accumulation at the regional scale over the last centuries by providing a new snow accumulation reconstruction that incorporates information from the Antarctic continent and from higher latitudes in the Southern Hemisphere. The relationships between the regional Antarctic snow accumulation and a wide range of climate variables over the Southern Hemisphere are first assessed in reanalysis data and climate models to identify the regions and data that are the most likely to improve reconstruction skill. Specifically, we will assess here the locations north of the Antarctic continent where relevant proxy data is found for Antarctic snow accumulation reconstruction. This will also be the opportunity to evaluate the ability of climate models to simulate observed teleconnections. Based on these results, we reconstruct the snow accumulation as well as the surface air temperature, atmospheric circulation and sea ice cover over the last centuries. This is achieved by data assimilation that is able to combine different types of records, taking advantage of their covariance as represented in climate models.

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Antarctica and Greenland ice sheet mass loss from multiple-satellite data, and impact on global and regional sea levels

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Understanding the long-term changes in the ice sheets of Greenland and Antarctica has global climate significance, especially on long term global and regional sea level rise predictions. We present results of current satellite-derived ice sheet change time series of Greenland and Antarctica, using satellites such as GRACE, GRACE-FO, CryoSat and IceSat, covering up to a 28 year time span, building in part on data available through the ESA Climate Change Initiative. The space data highlight the dynamic nature of the ice sheet changes, including the large interannual variation and regional accelerations of ice mass loss regions, which make short term predictions of ice sheet melt challenging due to decadal-scale regional climate changes. The accelerations of the ice sheet melt have direct impact on the sea level rise, with "fingerprinting" of these effects due to earth rheology and gravitational changes showing big changes in the vulnerability of different coastal regions to future sea level rise.

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A new conceptual model for interpolar climate coupling during the Ice Ages

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The thermal bipolar seesaw model by Stocker and Johnsen is widely used to explain the connection between abrupt Dansgaard-Oeschger events in Greenland and their climate response in Antarctica. We now have better-dated records from Greenland and Antarctica with higher resolutions which provide critical information into furthering our understanding of interpolar climate coupling. Records of water isotopic composition from Greenland and Antarctic ice cores were used as a proxy for past temperatures. MatLab was the primary tool used for data analysis, combining statistical correlation and modeling on the updated data sets. The data were first used to replicate the bipolar seesaw. WAIS Divide, Talos Dome, and EPICA Dome C produced the best depiction of the seesaw, whereas EPICA Dronning Maud Land and Dome Fuji had much lower correlations even though their proximity is closer to the South Atlantic. Next, we suggest a simple conceptual model that can replicate both millennial and orbital-scale Antarctic climate during the last ice age using greenhouse gas forcing, surface albedo, and the AMOC. Modeling results suggest Antarctic climate simply reflects the mean ocean temperature; in this view it is the global ocean interior, rather than the Southern ocean, acting as the heat reservoir in the bipolar seesaw. By using three AMOC states (strong, weak, and off), we can simulate the D/O cycle and glacial terminations, confirming the seesaw is a necessary part of the machinery of glacial cycles. The success of our simple model approach suggests a revised view of the seesaw concept may be warranted.

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Spatio-temporal terrestrial sediment input in the Bellingshausen and Scotia Seas and its implication for sedimentation mechanism since the last glacial period

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Magnetic susceptibility (MS) record of sediment cores from the Scotia Sea showed a strong correlation with ice core dust record, consequently the graphical correlation between them can be used for age model establishment. However, the exact mechanism is still controversial. In addition, this correlation is mostly found in the Scotia Sea, which limits our understanding. We found that the MS variation of a sediment core obtained in the Bellingshausen Sea continental rise shows a co-variation with ice core dust record. We document MS, CaCO3 concentration, and ITRAX scanned elemental ratios (Ca/Ti and Ti/Rb) of cores from the Bellingshausen Sea and the Scotia Sea to compare the temporal variation of terrestrial sediment input and its source region in the two regions. Ca/Ti is often used for biogenic carbonate/detrital ratio, but no relationship between CaCO3 concentration and Ca/Ti ratio, indicating that Ca/Ti ratio here can be used as a provenance proxy together with Ti/Rb. Although the variations of MS and Ca/Ti ratios co-vary (high during glacial periods), Ca/Ti and Ti/Rb ratios showed a longitudinal difference. This suggests that the MS variation from the Bellingshausen Sea to the Scotia Sea, even within the Scotia Sea, is not controlled by dust input and oceanic current which were previously proposed as the main mechanism. However, if it is controlled by ice shelf calving activity during glacial periods as recently proposed, the regional co-variation with different provenances can be explained well. Our study shows the glacial dynamics in the West Antarctica were synchronous.

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Paleoclimate change with diatom assemblage in the Ross sea coastal core sediment

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Study the climate change recorded in the core deposits at the Antarctic coast, the geochemistry data and the diatom assemblage in the piston core deposits (RS14-GC04) in the Ross Sea. The research area, the Antarctic Ross Sea, is a climate-sensitive area that is believed to have been affected by large and small climate changes during Holocene, which is recorded in the sedimentary layers of the seafloor. The variation of sediment core including diatoms were analyzed from the drilled core which was obtained from the Ross Sea for the purpose of reconstruction of the environmental variations during the Holocene. A total of 12 species and varieties belonging to 29 genera was identified from the core RS14-GC04. The diatom valves per gram of dry sediment range from 3.81×108/g~4.23×109/g in the core. Geochemistry data shows total nitrogen(TN) 0.014~0.233%, total carbon(TC) 0.234~1.508%, total organic carbon(TOC) 0.23~0.151%, biogenic opal(Bsi) 2.90~57.58%, magnetic susceptibility(MS) 0~545 SI 10-5. The results were divided into four facies. Appears in the grounding zone proximal to the open sea environment is seen in the lamination core sediment. When viewed as a position of the core, it appears well after the LGM climate records from the coast. Diatom and other microfossils are often used to restore past climate and environment in land and sea environments, and they are very important indicators of climate change in Antarctic environments. Through the analysis of the diatom assemblage, we want to learn more about the changes in the marine environment in the Ross Sea coast of Antarctica.

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Interhemispheric coupling of abrupt climate change: beyond the bipolar seesaw

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The thermal bipolar ocean seesaw hypothesis was advanced by Stocker and Johnsen, Paleo. [2003] as the simplest possible thermodynamic model to explain the relationship between Dansgaard-Oeschger (DO) and Antarctic Isotope Maxima (AIM) events. Their model invokes a Southern Ocean thermal reservoir, with its heat content modulated by changes in cross-equatorial heat transport by the Atlantic Ocean. Here, we test the seesaw hypothesis using palaeoclimate data and results from a 1-degree GCM that exhibits self-sustained DO oscillations [Vettoretti and Peltier, J. Clim., 2018].

We present four main results. (1) Changes in Atlantic heat transport during the DO oscillations are largely compensated by opposing changes in heat transport by the global atmosphere and Pacific Ocean. (2) Contrary to Stocker and Johnsen [2003], the Southern Ocean is not a major heat reservoir during DO-AIM coupling. This is because the Antarctic Circumpolar Current (ACC) strongly inhibits meridional ocean heat transport. (3) Antarctic warming during AIM events results from increasing poleward atmospheric sensible heat and moisture transport, following sea ice retreat in the Southern Ocean. (4) The Antarctic sea ice retreat is initiated by eddy-heat fluxes across the ACC (principally in the Pacific sector) and amplified by ice-albedo feedback. These results substantiate and expand on earlier work based on a 3-degree GCM [Pedro et al., Quat. Sci. Rev., 2018]. We conclude that the bipolar seesaw is useful heuristic model, but that it misses key processes in the interhemispheric coupling of abrupt climate change.

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Tropical Pacific and Indian teleconnections to Antarctica

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A multidecadal strengthening of the Amundsen Sea Low largely explains the increase in Antarctic sea ice concentration in the eastern Ross Sea and decrease in the Bellingshausen Sea since 1979. Following the long-term overall increase, Antarctic sea ice declined drastically during austral spring 2016, with influences proposed from the 2015/2016 extreme El Niño and a tropical Indian Ocean teleconnection. Here, we examine tropical Pacific and Indian teleconnections to Antarctic sea ice and the adjacent ice sheets using a suite of 'pacemaker' experiments.

The multidecadal strengthening of the Amundsen Sea Low is not captured by freely running coupled climate models, but can be reproduced in simulations of two independent coupled climate models: one constrained by observed tropical Pacific sea surface temperature anomalies and the other by observed tropical wind stress. This analysis further supports the phase change in the Interdecadal Pacific Oscillation from positive to negative over 1979–2013 as contributing to the observed strengthening of the Amundsen Sea Low.

We also conduct experiments using a full coupled climate model forced with observed tropical sea surface temperature to examine the impact of the Indian and Pacific Oceans on southern high latitudes during austral spring 2016. Our experiments suggest a Rossby wave teleconnection from the tropical Indian Ocean contributed to the sea ice decline during spring 2016, with less influence from the Pacific.

These results highlight the importance of accounting for teleconnections from low to high latitudes in both model simulations and observations of Antarctic variability and change.

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Glacier retreat and ocean-atmosphere interactions at King George Island – Antarctic Peninsula

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Glacier retreat is a fact, even in The Antarctic at King George Island (KGI). This study targets to determine glacier retreat and its relationship with climate variability. Multi-temporal analysis with satellite images (Landsat) from 1989 to 2019 and climatic assessment was made. We assess all glaciers located at Admiralty Bay and King George Bay; and additionally, an analysis over only Anna Glacier all of them at KGI. Notwithstanding; all studied glaciers are located at the same place, the glacier retreat rate is different. First, glaciers in direct contact with sea have lost more glacier coverage than the glaciers on continent zone. Second, there was at least equal glacier retreat for period 2005-2007 (only 2 years) and 2007-2014 (7 years).

The first insight over climatology and glacier retreat shows a negative correlation between SST at 3.4 zone - Pacific Ocean and SST around KGI. Consequently, each year evaluation of glacier retreats from 2014-2017 at KGI indicates that whilst the ENSO event (El Niño 2015-2016) occurred, less glacier coverage was lost regarding the normal remaining years (2014 and 2017). Nonetheless, the great glacier coverage loss of 2005-2007 cannot be explained in the same way because for this period, it had only developed a weak La Niña event at 3.4 zone (for such that glacier loss, it might be expected a strong La Niña event). Hence, it is important to understand the key role of ENSO events, SAM, SST, Calvin effect and/or a combination of various of them over glacier retreat at KGI.

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Teleconnections between Antarctic sea ice during autumn and the Indian summer monsoon

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The polar sea ice variability is crucial evidence for climate change. The sea ice variability has far-reaching consequences by affecting the global climate through teleconnections. The sea ice variability in both the hemisphere shows an opposite trend with Arctic sea ice diminishing and Antarctic sea ice increasing till the past few years. The present study examines how the Antarctic sea ice variability during March-May affects the interannual variability of the Indian summer monsoon. The interannual variability of the Indian summer monsoon is punctuated by drought, flood and normal monsoon years. The analysis for this study was done using observational, satellite, and global reanalysis datasets (the NCEP/NCAR and ECMWF Interim Re-Analysis). Preliminary results indicate that the drought years of the Indian summer monsoon are preceded by surface and tropospheric warming over the Indian Ocean sector of Antarctica and cooling over the Ross Sea Sector of the Western Antarctic, during March-May period and the opposite in the case of flood years. The impact of warming is reflected in the sea ice variability also. An important feature observed during the period from 1951 to 2014, is that the years prior and after 2000 differ in the intensity of warming. More analysis and Climate model simulations are required to fully understand the physical mechanism and teleconnections, through which the Antarctic warming(cooling) over the Indian Ocean sector (West Antarctica) sector influences the Indian summer monsoon.

Keywords: Antarctic sea ice, Monsoon, teleconnections

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Glacial-interglacial ACC dynamics in the Pleistocene: Biomarker and dinocyst-based reconstruction of paleoceanographic changes in the Southern Pacific Ocean

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The Antarctic Circumpolar Current (ACC) plays a crucial role in the redistribution of nutrients, upwelling of CO2-rich sub-surface water masses, and delivery of heat to the marine-terminating Antarctic ice sheet, strongly influencing melting rates and sea level rise, eventually. Yet, projections of its future behavior are hindered by the complexity of ACC-associated frontal system migration.

Here, we revisit Pleistocene sediments drilled during Ocean Drilling Program (ODP) Leg 189 around Tasmania. This region represents one of the sectors of the Southern Ocean where the frontal systems of the ACC reach their southernmost position, making it particularly vulnerable to ocean-induced Antarctic ice sheet melt.

We expand on previous work by Nürnberg et al. (2004) by applying organic geochemical as well as quantitative dinocyst assemblage-based proxies on Sites 1171 and 1172 in the Subantarctic Zone and north of the Subtropical Front, respectively, in order to reconstruct Pleistocene sea surface conditions, and thus draw conclusions about past ACC behavior. Our quantitative proxies record past oceanographic conditions, but their response to Southern Ocean frontal system migration has yet been sparsely documented. Additionally, new stable and radiogenic isotope data further improve the records' age models.

Special focus is given to MIS 11 and 5, representing very distinct interglacials and potential analogues for the near future climate under anthropogenic forcing. Preliminary results show strong changes between glacial-interglacial cycles, suggesting strong frontal system migration in this region. This has potential implications for the ocean-induced melting of the Wilkes Land ice sheet as anticipated for the future.

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Atmospheric re-organization during the late MIS3 period driven by local orbital forcing?

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Marine Isotope Stage 3 in Antarctica and Greenland has been a subject of many detailed studies for its characteristic millennial-scale warming events which evoked global impacts. These events, although generally described as oceanic teleconnections and controlled by changes in the North Atlantic climate, are also accompanied by quick and large-scale atmospheric re-arrangements in the form of changes in the latitudinal position of Intertropical Convergence Zone and Southern Hemisphere westerlies. Consequences of such re-arrangements include variability in the strength of the Asian monsoon/tropical precipitation, and changes in the rate of Southern Ocean upwelling, with the latter exerting a key control on atmospheric carbon dioxide concentration.

Here we present a new and high-resolution record of non-sea salt calcium, a proxy for continental dust/latitudinal position of Southern Hemisphere westerlies, from Roosevelt Island Climate Evolution ice core, a coastal record from West Antarctica, and a suite of other proxies, and examine the atmospheric re-organizations that occurred between 26-40 ka BP. We identify an increase in the mean concentration of continental dust in Antarctic ice cores after ~32ka BP, concomitant to the stadial conditions in Greenland, and henceforth we suggest this to be a result of equator-ward displacement of the Southern Hemisphere westerlies. The major implications of such a reorganization include the intensification of Asian monsoon/tropical rainfall and reduction in atmospheric carbon dioxide. Since this time period coincides with Southern Hemisphere summer insolation minima, we propose that a cooling of the Southern Ocean and subsequent sea ice expansion may have triggered this global-scale atmospheric re-arrangement.

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SESSION 9

CRITICAL CHALLENGES IN MODELLING PAST AND FUTURE EVOLUTION OF THE ANTARCTIC AND GREENLAND ICE SHEETS - SCALES, UNCERTAINTY, PROCESSES, IMPLICATIONS FOR SEA LEVEL

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Rupert Gladstone, Adam Treverrow, Felicity McCormack, Chen Zhao
Co-Convened with the IASC Cryosphere Working Group (Guðfinna Th Aðalgeirsdóttir)

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Using triple water isotopes signatures of surface snow to gauge metamorphism in Antarctica

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Water isotopic composition is a key proxy for past climate reconstructions using deep ice cores from Antarctica. As precipitation forms, the local temperature is imprinted in the snowfalls $\delta^{18}O$. However, this climatic signal can be modified after snow deposition when snow is exposed to the atmosphere for a long time in regions with extremely low accumulation. Understanding this effect is crucial for the interpretation of ice core records from the extremely dry East Antarctic Plateau, where post-deposition processes such as blowing snow or metamorphism affect the physical and chemical properties of snow during the long periods of snow exposure to the atmosphere. Despite the importance of these processes for the reliable reconstruction of temperature from water isotopic composition in ice cores, the tools required to quantify their impacts are still missing. Here, we present a first year-long comparison between (a) time series of surface snow isotopic composition including d-excess and ^{17}O-excess at Dome C and (b) satellite observations providing information on snow grain size, a marker of surface metamorphism. Long summer periods without precipitation tend to produce a surface snow metamorphism signature altering the climatic signal in the surface snow $\delta^{18}O$ Using a simple model, we demonstrate that d-excess and ^{17}O-excess allow the identification of the latent fluxes induced by metamorphism, and their impact on surface snow isotopic composition. In turn, their measurement can help improve climate reconstructions based on $\delta^{18}O$ records ice by removing the influence of snow metamorphism.

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The Ice Shelf Lasagne: effects of marine ice on ice shelf dynamics and stability

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Layers of marine accreted ice form at the base of many Antarctic ice shelves, and can account for a significant proportion of the overall shelf thickness. These layers contain a considerable amount of soluble and insoluble impurities, which have been shown to affect the rheological properties of ice on a small scale. However, it is not clear to what extent these marine ice layers can affect the broader dynamics and thermal structure of an ice shelf. We performed a series of deformation experiments on marine ice from the Amery Ice Shelf under quasi-in situ conditions, and compared the results with experiments performed on pure water ice. These experiments reveal the impact of impurities on material structure and rheology, with implications for the deformation of ice in large scale numerical ice shelf simulations.

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Progress towards coupling ice sheet and ocean models

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With recent developments in the modelling of Antarctica and its interactions with the ocean several coupled model frameworks now exist. This talk will focus on presenting the Framework for Ice Sheet - Ocean Coupling (FISOC), developed to provide a flexible platform for performing coupled ice sheet - ocean modelling experiments. We present progress and preliminary results using FISOC to couple the Regional Ocean Modelling System (ROMS) with Elmer/Ice, a full-Stokes ice sheet model. Idealised experiments have been used that also contribute to the WCRP Marine Ice Sheet-Ocean Model Intercomparison Project (MISOMIP). A recent focus is on testing emergent behaviour of the coupled system and the model numerics. The talk will outline future technological applications and developments conducted as part of a broader international consortium effort. These efforts include coupling to sub-glacial hydrology, sea ice and atmospheres to form a complete system-downscaling technology from which to examine the influence of future climate on ice sheet evolution and hence sea level and global climate impacts. Developments to apply the technology to the Greenland Ice Sheet are presently underway.

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Choice of melt parameterization determines the faith of Totten glacier, East Antarctica

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Totten glacier is draining 68% of the Aurora basin, East Antarctica, - an equivalent to 3.5m global sea level rise. Further, Totten's thickness and velocity have been fluctuating during the last decades showing periodic speed-ups and thinning. We investigate the effect of different ocean forcing on Totten glacier using the state-of-the-art ice sheet model BISICLES and based on the high-resolution data sets BedMachine Antarctica and REMA (Morlighem et al., 2019; Howat et al., 2019). Our simulations (2015-2100) are following the ISMIP6 setup and are based on CMIP5 & CMIP6 AOGCM outputs under RCP8.5 and RCP2.6. The contribution to sea level at 2100 varies between plus 20mm and minus 8mm. For all scenarios, we see thinning at the sides of Totten glacier in the slower flowing areas, but only climate models with sub-shelf melt rates that are at least 8m/a above the reference melt rates (1995 - 2017) lead to thinning and acceleration across Totten's grounding line.
In agreement with ISMIP6 results, nonlocal quadratic melt rates adjusted to present day conditions at Pine island glacier, West Antarctica, results in the highest sub-shelf melt rates for all AOGCMs (up to 80m/a locally).
The ISMIP6 ocean melt scheme is based on a feedback given the simulated ice draft change: the thermal forcing of the ocean model is taken from the ocean layer closest to the bottom of the ice shelf at the current simulation step. Simulations not including this feedback lead to higher mass loss than the standard ISMIP6 scenario including the feedback.

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A data-constrained large ensemble of the Antarctic ice sheet evolution over the last glacial cycle: Toward a Bayesian calibration

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To better interpret contemporaneous change of the Antarctic ice sheet and to make improved predictions of its future sea-level contribution, reconstructions of past ice sheet evolution are required. A Bayesian calibration of a glaciological model against paleo and present-day observational constraints offers a rigorous route to quantify robust uncertainty estimates. Transient continental-scale reconstructions over glacial cycles require glaciological models, but the latter depend on parameterisations to account for deficiencies inherent in any numerical model. Recent studies have explored parametric uncertainties with only a few ensemble parameters, this work is distinguished by a much stronger emphasis on quantifying all model uncertainties.

An updated Glacial Systems Model (GSM) is used to simulate the Antarctic ice sheet over the last glacial cycle using more than 30 ensemble parameters. The GSM ice sheet model consists of hybrid SIA-SSA dynamics, Schoof grounding line scheme, hydrofracturing and ice cliff instability mechanisms, temperature-dependent sub-shelf melt scheme, visco-elastic glacial isostatic adjustment, and a broader than previous climate forcing. A Latin hypercube sampling of the parameter space was completed to verify the GSM’s ability to envelope observational constraints. The calibration employs Bayesian neural network emulators of the GSM to permit multi-million MCMC sampling from the posterior probability distribution for GSM ensemble parameter vectors.

The large ensemble results presented here consist of over 10000 data-constrained transient model runs. Preliminary results of the Bayesian calibration are shown as confidence intervals of key metrics including the Antarctic equivalent sea-level contribution to the last interglaciation, LGM, MWP-1a, and present-day glacial isostatic adjustment estimates.

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Exploring the effects of parameter and climate forcing uncertainty on past and future Antarctic Ice Sheet grounding-line retreat

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In future projections of global sea level, the contribution of the Antarctic Ice Sheet (AIS) is one of the most uncertain aspects. In particular, the AIS response to future climate warming scenarios varies widely in numerical ice sheet models, related to uncertainty in model parameter selection and parameterizations of physical processes, such as sub-ice shelf melting. Here, we present the results of two ice sheet model ensembles using the Parallel Ice Sheet Model (PISM) that investigate the influence of model parameter selection on ice sheet sensitivity to ocean and atmosphere forcing. The first ensemble focuses on deglacial ice sheet retreat in the Ross Embayment, Antarctica's largest catchment. The results demonstrate that while the atmosphere forcing influences the initial timing of grounding-line retreat, ocean forcing becomes the dominant control on grounding-line migration following the formation of the Ross Ice Shelf. However, these relationships are strongly modulated by the mantle viscosity and an enhancement factor of the shallow shelf approximation, which can enhance or diminish ice sheet sensitivity to climate forcing. The second ensemble is based on the projection experiments of the Ice Sheet Model Intercomparison Project 6 (ISMIP6) of the next century. Model parameters are systematically explored to demonstrate their influence on the ice sheet response to climate forcing. Additionally, we compare different methods of sub-ice shelf melt parameterization. The results highlight the regions and factors of greatest uncertainty, where additional constraints for numerical ice sheet models are most useful.

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Spatial distribution of englacial layer slope as a constraint on ice sheet basal conditions

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Englacial layers are a ubiquitous indicator of internal deformation within ice sheets, as well as a common finding in radio echo sounding data. In spite of this, placing direct constraints on present or past ice flow through englacial layers remains, to date, a challenging task. Our work leverages recent advances in the processing of airborne radar sounding data along with modelling work to address this challenge. Here we present an application to the case of an abrupt change in basal friction due to a transition from frozen to temperate basal conditions, which we seek to detect from radar sounding data through its signature in englacial layer geometry. We first formulate a first-principle model for ice flow across an abrupt change in basal friction, and use it to show that this setting produces quantifiable, large, anomalies in layer slope. Then we exploit a recently developed layer-optimized, unfocussed SAR processing technique that automatically estimates layer slopes with high accuracy to look for this signature in the onset region of Institute Ice Stream (West Antarctica). We find that observed slopes are incompatible with an abrupt sliding initiation. Our results instead provide evidence for the existence of a slow (in space) transition from fully frozen to temperate beds, as consistent, for instance with a spatially extended region of subtemperate sliding. We conclude by discussing implications of this finding with respect to the present and past history of Institute Ice Stream.

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Modelling the deformation regime of Thwaites Glacier using the ESTAR flow relation

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Polar ice sheets flow by a combination of viscous deformation and basal sliding. Sliding is generally assumed to dominate in fast-flowing regions, while deformation dominates in slow-flowing regions and in ice shelves. The reliability of model estimates of deformation are limited by the Glen flow relation - the standard in most large-scale ice sheet models - that does not capture the steady-state flow of anisotropic ice that prevails in polar ice sheets. We compare the simulated deformation regimes of Thwaites Glacier, West Antarctica, using the Glen flow relation and the ESTAR (empirical, scalar, tertiary, anisotropy regime) flow relation – a new description of deformation that takes into account the impact of different types of stresses on the flow regime. On grounded ice, differences emerge in the balance between basal shear and gravitational stresses via the mediating effect of the membrane stresses. In regions where bed-parallel vertical shear controls flow, the basal shear stresses in the ESTAR simulation are closer to the local driving stresses than in the unenhanced Glen flow relation, the role of the membrane stresses in the latter being correspondingly greater. In slow-flowing regions, ESTAR predicts deformation-dominated flow, but the Glen flow relation simulates physically-unrealistic sliding-dominated flow. On the Thwaites Glacier Tongue, the ESTAR simulation matches observed surface velocities better through accounting for the influence of polycrystalline anisotropy on deformation rates. Our results highlight the importance of considering anisotropic ice and its influence on simulated stress configurations, including how the local driving stresses are transmitted to the bed.

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Hiatus of mass losses from Hurd and Johnsons glaciers, Livingston Island, during the regional cooling period 2002-2016 of the Northern Antarctic Peninsula

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The Antarctic Peninsula (AP) region and its surroundings, including the South Shetland Islands, underwent a sustained and intense warming during the second half of the 20th century. However, during the first fifteen years of the current century, the northern part of the AP and the South Shetland Islands have experienced a sustained cooling, with a decrease in average temperatures in the order of 1ºC over such a short period. The regional temperatures over the last 4 years seem to indicate that the regional cooling has come to an end. In spite of the short temporal scale of this cooling period, glacier surface mass balance (SMB) is a non-delayed response of glaciers to changes in atmospheric forcing. Therefore, it is not surprise that the SMB of the small glaciers in this region (among them, Hurd and Johnsons glaciers, on Livingston Island) have experienced a change in mass-balance regime, from mass losses until fairly recently to mass gains during the second part of the cooling period. In this contribution, we analyse the mass-balance evolution of Hurd and Johnsons glaciers in the context of recent regional climate variations. The set of glaciological SMBs for the period 2002-2016 is complemented by the calculation of the geodetic mass balance over the period 2000-2013, the estimate of the mass losses by iceberg calving from Johnsons Glacier, and the estimation of the total mass balance of Hurd and Johnsons glaciers during 2002-2016, which shows that both glaciers have been close to equilibrium during this period.

1548

Aurora Basin, the weak underbelly of East Antarctica

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The East Antarctic Ice Sheet (EAIS) is a major component of the global sea level budget; yet, uncertainty remains in how this ice sheet will evolve in a changing climate system. To address this uncertainty, we model the most dynamic catchments of EAIS out to 2100 using the Ice Sheet System Model. We employ three basal melt rate parameterizations to resolve ice-ocean interactions and force our model with anomalies in both surface mass balance and ocean thermal forcing from both CMIP5 and CMIP6 model output. We find that this sector of EAIS gains up to 20 mm SLRe by 2100 under high emission scenarios and loses mass under low emission scenarios. All basins within the domain either gain mass or are in near mass balance through 2100 except the Aurora Subglacial Basin. The primary region of mass loss in this basin was located within 50 km upstream of Totten Glacier's grounding line, which loses up to 6 mm SLRe by 2100. Glacial discharge is modulated by buttress supplied by a 10 km ice plain, located along the southern-most end of Totten's grounding line. This ice plain is sensitive to brief changes in ocean temperature and once ungrounded, glacial discharge from Totten accelerates by up to 70% of it present day configuration. In all, we present plausible bounds on the contribution of a large sector of EAIS to global sea level rise out to the end of the century and target Totten as the most vulnerable glacier in this region.

1231

An ensemble of dynamically simulated deglacial models constrained by geological observations

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There is still significant uncertainty in the volume of Antarctic ice at the last glacial maximum and its evolution to present day. The change in surface loading through time is a primary input into glacial isostatic adjustment models used to correct gravimetry measurements of present-day change. We use the Parallel Ice Sheet Model (PISM) to simulate the evolution of the Antarctic Ice Sheet from the last interglacial to the present day. Using the coupled earth deformation model within PISM and an ensemble method we test four palaeo-climate scenarios, three mantle viscosities and sixteen different glaciological parameter sets which vary ice flow enhancement and basal resistance to create 196 deglacial histories. We sieve the simulation for present day volume and ice shelf area , then score the performance of each model member against palaeo and present-day observations of ice thickness, ice thinning rates and ice area. Using the climate scenario and mantle viscosity that provided the best fit to the observational constraints, we expand the glaciological parameter space, with 440 additional ensemble members. The top 10 scoring simulations have an additional volume range of 11 to 14 m sea level equivalent at the last glacial maximum compared to the present day. These top members retreated to a minimum ice sheet volume range of -0.1 to -1.55m below present-day volume in the mid-Holocene before regaining volume towards the present day.

1377

The Priestley Glacier Deformation experiment

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Ice deformation plays a critical role in ice sheet and glacier flow. Flow laws used to model ice deformation come primarily from laboratory experiments. A laboratory experiment to simulate steady-state deformation needs a strain of at least 20%. Experiments that achieve this strain, using an isotropic starting material, are only realistic at rates that are two or more orders of magnitude faster than natural deformation rates. Using flow laws always requires extrapolation to lower strain rates and because of this it is important to identify natural systems that provide a test of that extrapolation.
Lateral shear zones at the margins of outlet glaciers and ice streams can be considered as natural experiments, in that it is possible to measure the strain rate and temperature and to characterise the ice anisotropy through seismology and radar methods. It is also possible to collect samples that allow ice physical properties to be measured and ice chemistry to be analysed. Critically difficult is the constraint of the stress tensor in the shear zone: modelling approaches and re-deformation experiments of samples both provide possible pathways to constraining components of the stress tensor.
We have completed two field seasons on the shear margin of the Priestley Glacier, that flows into the Nansen Ice shelf, Terra Nova Bay, Antarctica. We conducted field geophysics and collected cores to 58m depth in the shear zone. We will present preliminary results from seismic, pRES and surveying data. The seismic data highlight anisotropy consistent with shear constrained from the survey data.

1372

Flow laws for ice sheet modelling: what do experiments tell us?

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Researchers are recognising rapid changes occurring at the ice-ocean interface: changes that potentially increase the driving force for sea-ward motion of ice sheets. Estimation of the time-scale of the ice sheet response and resultant sea-level rise depends critically on realistic ice flow laws. Ice deformation is a significant component of ice flow: data from laboratory experiments can be extrapolated to natural strain-rates.

The strain rate at a given stress results from the addition of the rates related to grain-size sensitive and grain-size insensitive mechanisms. All ice experiments, where grain-size has been varied, show grain-size dependency at low strain (< 3%). As strain increases to intermediate (~20%) values, viscosity reduces corresponding to changes in fabric and grain-size. At strains higher than 20% to 50% an approximately steady-state viscosity is achieved, corresponding to microstructural steady-state.

At low strains, the strain rate dependency on stress (stress exponent: n) depends on ice grain-size and conditions (particularly stress) and varies between ~ 2 and ~ 4. Intermediate n values (3 to 3.5) are common and have little relevance to ice deformation at high strain.

Grain-size at steady-state is inversely proportional to the flow stress, through a piezometer relationship. At steady-state, grain-size sensitive mechanisms contribute significantly to deformation, but because the stress controls the grain-size, which in turn controls the viscosity these effects are hidden. Experimental steady-state flow laws have n values of ~ 4 or higher: these are applicable to ice at high strain and match recent estimates from natural systems.

1514

Glacial isostatic adjustment and how the past can help constrain the future: The GLAC-GR2 joint glaciological and earth rheology Bayesian calibration for the last glacial cycle of the Greenland ice sheet

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What impact does glacial isostatic adjustment (GIA) and how it's represented have on centennial scale future projections of Greenland ice sheet change? And how should the process be confidently represented?

To answer these questions, we use the 3D Glacial Systems Model (GSM) with coupled GIA (global visco-elastic rheology with first order gravitational correction and accounting for ice load contributions from other sheets). To answer these questions confidently, we carry out a Bayesian calibration of the GSM. Calibration constraints include a large set of relative sea level observations, cosmogenic ages, and borehole temperature records from the Greenland ice core sites. Bayesian artificial neural network emulators of the GSM enable multi-million point MCMC sampling. The calibration is over two model grid resolutions (0.5X0.25 degrees lonXlat and 0.25X0.125 degrees) and model runs are over the last two glacial cycles. Calibrated model parameters address uncertainties in: ice calving and submarine melt, basal drag, deep geothermal heat flux, and earth viscosity structure.

Calibration results will be presented for regional lithospheric thickness, and (upper and lower) mantle viscosity. To answer our opening question about the impact of GIA on future projections, we present the results of running a high probability subset of model runs into the future, and examine the sensitivity to imposed earth rheology and the turning off of the physical memory of past GIA. The calibration has a much higher posterior probability for soft earth models (thin lithosphere and soft upper mantle viscosity) compared to that of previously published ensemble based inversions.

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Water chemistry and ice mechanics

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Laboratory experiments have been used to quantify the creep behaviour of pure polycrystalline ice. These are the basis of flow laws, such as the Glen flow law, which describe the strength of ice for given applied stresses and temperatures and are crucial in modelling the flow of bodies of ice, and their response in a warming climate. However, these laws typically assume ice is free of soluble (chemical) and insoluble (particulate) impurities. This is unrealistic in natural ice. Past work has shown impure ice tends to be weaker than pure ice, as intracrystalline impurities should encourage the internal deformation of grains. As ice flows, the impurities are swept to grain boundaries and inhibit grain growth by grain boundary pinning. This is seen in natural ice cores, with higher concentrations of ionic species found in finer grained bands of ice. The effects of chemistry have proven difficult to quantify, as different chemical species appear to behave differently; Recent work has shown Ca2+ ions have a hardening effect, while H2SO4 enhances creep rates in ice. In this study, ice with major ion chemical compositions comparable to coastal and central Antarctic ice has been synthesised, and deformed in a series of uniaxial compression experiments at varying strain rates (10-4, 10-5, 5x10-6 s-1) and temperatures (-10 and -30°C) at the University of Pennsylvania. Mechanical data suggest chemistry has no significant effect on the strength of ice. This suggests insoluble impurities or higher ionic concentrations than those studied contribute to the softening of natural ice.

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Ice front blocking of ocean heat transport to an Antarctic ice shelf

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Mass loss from the Antarctic Ice Sheet to the ocean has increased in recent decades, largely because the thinning of its floating ice shelves has allowed the outflow of grounded ice to accelerate. Enhanced basal melting of the ice shelves is thought to be the ultimate driver of change, motivating a recent focus on the processes that control ocean heat transport onto and across the seabed of the Antarctic continental shelf towards the ice. However, the shoreward heat flux typically far exceeds that required to match observed melt rates, suggesting other critical controls. Here we show that the depth-independent (barotropic) component of the flow towards an ice shelf is blocked by the dramatic step shape of the ice front, and that only the depth-varying (baroclinic) component, typically much smaller, can enter the sub-ice cavity. Our results arise from direct observations of the Getz Ice Shelf system and laboratory experiments on a rotating platform. A similar blocking of the barotropic component may occur in other areas with comparable ice-bathymetry configurations, which may explain why changes in the density structure of the water column have been found to be a better indicator of basal melt rate variability than the heat transported onto the continental shelf. Representing the step topography of the ice front accurately in models is thus important for simulating the ocean heat fluxes and induced melt rates.

1481

Influence of the bathymetry and pinning points on the Lambert-Amery glacial system ice flow

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The Lambert-Amery Glacial System (LAGS) is a major drainage basin of East Antarctica, one of the largest glacial systems on Earth, but the spatial variability of the bathymetry underneath the AIS is largely unknown. This bathymetry has a strong control on ice dynamics, through the presence of pinning points and its impact on the evolution of the grounding line. Here we use a numerical ice sheet model at 5 km resolution to assess the influence of the bathymetry, and topographic rises on ice dynamics. We first simulate a present day configuration to obtain a steady state that fits closely to present day observations. The steady state is perturbed by changing the geometry to investigate the sensitivity of the LAGS to bathymetry, on both large and small scales. Our results show that the bathymetry is not only crucial for reproducing grounding line dynamics, but also that the presence of pinning points on the floating ice shelf can have far-reaching impacts on ice flow, even when the pinning points are of small topographic scale. Pinning points are found to be critical for reconstructing the calving front position of the ice shelf. On the basis of these sensitivity tests, we show that an undersampled bathymetry can lead to undue emphasis on poorly constrained parameters to reproduce ice shelf extent. This shows the complex feedback between ice dynamics and the geometry of the bathymetry, and its importance in future modelling for the LAGS.

SCAR 2020

Antarctic Science - Global Connections

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SESSION 10

CLIMATE-ICE-OCEAN DYNAMICS OF ANTARCTICA'S COAST AND ICE SHELVES

Ted Scambos
David Vaughan, Vikram Goel

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Assessing controls on Antarctic Peninsula glacier dynamics using a numerical ice flow model

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Since the collapse of the Larsen A and B ice shelves on the eastern Antarctic Peninsula, ice flow from the shelves' former tributary glaciers has accelerated significantly. Here, I use a numerical ice flow model to investigate the influence of changing ocean conditions on Crane Glacier, former Larsen B tributary, following the collapse of the ice shelf. Specifically, I use high-resolution satellite imagery observations of speed, terminus position, and elevation change, bed elevations from NASA's Operation Ice Bridge mission, surface mass balance estimates from the RACMO2.3 climate model, and tune the calving and submarine melting parameterizations that define the ocean boundary conditions to calibrate the numerical model so that it reproduces temporal patterns in speed and elevation. The calving and submarine melting parameterizations are tuned using observations of terminus position (for calving) and surface meltwater runoff and iceberg melting (for submarine melting) to assess the influence of ocean change on changes in glacier dynamics. This research will contribute to both local and global understanding of glacier sensitivity to changing ocean conditions.

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Distribution and seasonal evolution of supraglacial lakes on Shackleton Ice Shelf, East Antarctica

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Supraglacial lakes (SGLs) enhance surface melting and can influence the structural integrity of ice shelves. However, the seasonal evolution of SGLs and their potential influence on ice shelf stability in East Antarctica remains poorly understood, despite high SGL densities on a number of potentially vulnerable ice shelves. Using optical satellite imagery, air temperature from climate reanalysis data and modelled melt predictions, we provide the first multi-decadal analysis (2000-2019) of seasonal SGL evolution on Shackleton Ice Shelf, Antarctica's northernmost remaining ice shelf which buttresses Denman Glacier. The ice shelf experiences locally high surface melt rates (>200 mm w.e. yr -1) and has the potential to support extensive melt ponding. In a typical melt season, we found hundreds of SGLs were, on average, 0.02 km2 in area, 0.9 m deep, and held a total meltwater volume of 5.9 x106 m3. At their most extensive, SGLs covered an area of 53.5 km2, but were clustered towards the grounding line, where densities approached 0.27 km2 per km2. Here, their development is linked to an albedo-lowering feedback associated with katabatic winds, the presence of blue ice and exposed rock. The SGLs drain supraglacially, through the ice, or refreeze at the end of the melt season. SGLs are more extensive and hold a greater volume of meltwater during years with warmer mean DJF near-surface temperatures and more short-lived, high magnitude modelled snowmelt events. Our analysis provides important constraints on the boundary conditions of supraglacial hydrology models and numerical simulations of ice shelf stability.

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Rapid transient response of Antarctic basal melt rates to changes in precipitation

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Ocean-driven melting of Antarctic ice shelves remains poorly understood and challenging to simulate, despite its importance for ice sheet stability and global sea level rise. As we seek to improve model representation of Antarctic melt, both over the historical period, and for future projections, we need to better understand how biases and uncertainty in forcing can affect the simulated ice shelf melt. In particular, climate models differ in the magnitude and spatial patterns of precipitation over the Southern Ocean and near the Antarctic coast. Biases in precipitation can have significant impact on the shelf water mass properties, sea ice production, convection and sub-ice shelf melt rates.

In this study, we examine the transient response of basal melt rates to precipitation, using a 5km-resolution pan-Antarctic ROMS configuration with thermodynamically coupled (static) ice-shelf cavities. We perform sensitivity experiments covering the spread of CMIP5 historical precipitation, by scaling a historical precipitation climatology derived from a climate model (ACCESS1.3 downscaled by MAR). These simulations provide insight on the processes governing the transient response of ocean properties, sea ice, and basal melt, as well as the timescales associated with these responses.

1686

Constraining sub-ice shelf channel evolution and melt rates in West Antarctic ice shelves

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Antarctic ice shelves buttress against the sea level rise contribution of the Antarctic Ice Sheet, but they are vulnerable to mass loss from surface and basal melt as well as the calving of icebergs. Sub-ice shelf melt channels (basal channels) have become a focus of ice shelf research due to their prevalence on ice shelves, and they have been associated with enhanced, localized basal melting as well as enhanced ice shelf fracturing. However, their short-term behavior and impact on ice shelf stability is largely unknown. We investigate basal channel evolution using a suite of high resolution surface elevation and ice thickness data. Estimating melt rates remains a challenge because current surface mass balance estimates do not resolve the spatial variability that has been observed above basal channels, and because the ice above basal channels may not be in hydrostatic equilibrium, so ice shelf thickness change cannot simply be calculated from surface elevation change. We work toward constraining the hydrostatic imbalance above basal channels in order to more accurately estimate thinning and melt rates. We observe a variety of evolutionary behaviors in our investigation of several West Antarctic ice shelves, including consistent channel position and size (no melt), active basal melt and ice shelf thinning at channels heads, and migration of channels toward western shear margins (indicating preferential melt on the western channel flanks). In general, unchanging channels and wide channels are more likely to be in hydrostatic equilibrium, making it easier to estimate basal melt rates in these channels

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Using structure-from-motion to produce ~55-year-old hypsometry changes for the Dotson and Crosson Ice Shelves from trimetrogon aerial imagery

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For the past ~25 years, research has shown that the Dotson and Crosson Ice Shelves have undergone considerable change in their thickness and strain field as the grounding lines of their tributary outlet glaciers (predominantly Smith and Kohler Glaciers) have been retreating. It is hypothesized that these changes are due to melt in the sub-shelf cavity by Circumpolar Deep Water, but some studies suggest dynamic thinning as another potential mechanism. Altimetry and optical satellite data observations reveal that the thinning and grounding line retreat has been relatively constant since the mid-1990s; however, since there are no published data of these parameters prior to 1990, the temporal extent of thinning and retreat is unknown. Numerical model results propose that the outlet glaciers were in a steady state prior to 1970, but without vertical and positional measurements from this time period, these projections have not been validated. To better conceptualize the pre-1990 state of the region and examine the pre-1970 configuration, we use trimetrogon aerial imagery collected in 1966-67 to generate ~55-year-old surface elevations using structure-from-motion processing techniques. We determine pre-1970 steady state from changes in elevation which are estimated by differencing the historical elevations with present-day surface heights and change rates. By extending the timeline of hypsometry for the Dotson and Crosson Ice Shelves, we improve our understanding of whether behavior of the last ~25 years is a discrete incident or part of a long-term phenomenon. Our aim is to improve the constraints necessary for enhanced predictive and hindcast modeling.

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Coupling Antarctic Ice-shelf Basal Melting in an Earth System Model

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Freshwater flux from the Antarctic Ice Sheet, which predominantly occurs through ice shelf basal melting and iceberg calving, is one of the largest sources of uncertainty regarding sea-level rise in a changing climate. Yet these processes are generally poorly represented in current Earth System Models (ESMs). As a step towards full and dynamic ice sheet coupling in an ESM, the U.S. Department of Energy's Energy Exascale Earth System Model (E3SM) has the capability to simulate ocean circulation within static ice shelf cavities, which is used to calculate ice shelf basal melt rates. Here, we present results from global simulations using these capabilities, in both fully coupled (active ocean, sea-ice, atmosphere, and land) and partially coupled (active ocean/sea-ice with prescribed atmospheric forcing) configurations. We assess the sensitivity of the modeled melt rates to changes in the region's climate, including freshening on the continental shelf and shoaling of the thermocline, which may then allow warmer deep waters to intrude into the ice-shelf cavities, further increasing melting. We also show that ice-shelf meltwater feeds back onto the broader regional climate, for example, by affecting melting under neighboring ice shelves, sometimes dramatically so. We demonstrate that significant reductions in melt-rate biases can be achieved through modifications to ocean model mixing parameterizations in E3SM. We also see significant differences in the degree of interannual-to-decadal variability in melting between ice-shelves.

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Temporal variability in basal melt rates on the Amery Ice Shelf

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The Amery Ice Shelf is the third largest ice shelf in Antarctica, draining approximately 16% of East Antarctica. The ice shelf has a very deep grounding line (~2500 m below sea level) driving locally high basal melt rates due to the pressure-dependence of the melt point of ice. Basal melt is highly variable on the shelf, including a large region of re-freezing along its western flank. Previous studies have indicated cyclonic ocean circulation beneath the ice shelf, with high salinity shelf water entering the ice shelf cavity in the east and outflow of ice shelf water and marine ice formation in the west. The heat content of the incoming shelf water can be highly variable on interannual timescales.

We present a multi-year, high-density timeseries of basal melt rates from the Amery Ice Shelf, collected using Autonomous phase-sensitive Radio-Echo Sounders (ApRES). Results are supported by independent measurements of basal melt derived from CryoSat-2 satellite data and a borehole-deployed acoustic Doppler current profiler (ADCP). These instrument datasets indicate that basal melt rates are highly variable on a range of timescales, indicating a complex ocean environment within the ice shelf cavity. We discuss what can be learned from our in situ measurements, and how they can be used to validate and improve oceanographic models, feeding into models of the glacier's future behaviour.

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Turbulence Observations beneath the Larsen C Ice Shelf, Antarctica

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Antarctic ice shelves restrain the flow of grounded ice into the ocean, and are thus an important control on Antarctica's contribution to global sea level rise. Ice shelves interact with the ocean beneath them, and the transfer of heat through the ice shelf-ocean boundary layer is critical in setting the basal melt rate and the sub-ice shelf circulation. The physics of this boundary layer is poorly understood however, and its inadequate representation in numerical models is hampering our ability to predict the future evolution of Antarctic ice shelves and global sea-level rise. Using a hot-water drilled access hole, two turbulence instrument clusters were deployed beneath the southern Larsen C Ice Shelf in December 2011. Both instruments returned a year-long time series of turbulent velocity observations, providing a unique opportunity to explore the turbulent processes at two depths within the ice-ocean boundary layer. Our results show that although the scaling between the turbulent kinetic energy (TKE) dissipation rate and mean flow speed varies with distance from the ice shelf base, the TKE dissipation rate is balanced entirely by the rate of shear production. The freshwater released by basal melting plays no role in the TKE balance. Ultimately the aim of these observational efforts is to better constrain our parameterisations of the boundary layer in large-scale numerical models, allowing more accurate simulations of ice shelves to be made under the warming climate.

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Constraining an ocean model under Getz Ice Shelf, Antarctica, using a gravity-derived bathymetry

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Getz Ice Shelf in West Antarctica is the largest producer of ice shelf meltwater in Antarctica, buttressing glaciers with enough ice to raise sea-level by 22cm. We present a new bathymetry of the Getz sub-ice shelf cavity using a three-dimensional inversion of airborne gravity data constrained by multibeam bathymetry data at sea and a reconstruction of the bed topography from mass conservation inland. The bathymetry is more than 500m deeper than previously estimated, with wider seafloor channels and a steeper transition with grounded ice. When incorporated into an ocean numerical model, the new bathymetry provides a better description of the spatial distribution of ice shelf melt, specifically along the grounding lines of the glaciers. While the melt intensity is overestimated due to a positive bias in ocean thermal forcing input, the study reveals the main pathways along which Circumpolar Deep Water enters the cavity and corroborates the observed rapid retreat of Berry Glacier along a deep, wide, retrograde channel.

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A Structural Glaciological Analysis Reveals Ice Shelf Calving Regime Change

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Over the last two to three decades changes in the calving regimes of several Antarctic ice shelves have been observed. These changes have been found to be predominantly driven by alterations in atmospheric and/or oceanic conditions. Understanding the mechanisms responsible for ice shelf calving, as well as how these mechanisms interact and evolve, is key to predicting the vulnerability of Antarctic ice shelves to future calving regime change. Changes in the calving regimes of ice shelves can influence their buttressing potential, and ultimately, the throughput of mass to the ocean. We performed a structural glaciological analysis of changes in structures on the Sørsdal Glacier, East Antarctica, in order to identify the glacial features that drive calving. These features were investigated for their interaction and evolution using surface elevation data in conjunction with a time-series of satellite imagery. We identified the presence of rifts, surface and basal crevasses, as well as basal channels. A complicated relationship was found to exist between basal channel geometry and the other glacial features, where a change in basal channel shape influenced the propagation of basal crevasses and the formation of rifts, and hence the stable calving front position (due to rifts and basal crevasses being the primary drivers of calving). These findings indicate that the calving regime of the Sørsdal Glacier exhibited change without obvious oceanic or atmospheric drivers, suggesting that the calving regimes of Antarctic ice shelves are not static, even the ice shelves not experiencing noticeable changes due to global warming.

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Breaking Better: including rifts in ice shelf models

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Through-cutting, laterally propagating rifts become the boundaries along which icebergs calve, thereby determining the position of the ice shelf front. Shelf front position, in turn, is both a forcing on and response to the conditions that drive ice shelves to change over time. Simulation of past and future ice shelf change thus requires some ability to represent rift propagation computationally. We are developing an approach to embed rifts explicitly in a computational ice flow model, and here we present validation studies using rifts in Ross Ice Shelf. We show that a linear elastic fracture mechanics approach explains their behaviour and that embedding rifts explicitly improves representation of shelf-wide stresses and rift propagation.

We use the extended finite element method to model rifts in elastic sub-domains on which we impose shelf-equivalent stress fields by calculating equivalent nodal forces. We have validated our routines using classic analytical test cases. The next step is to determine whether or not embedding rifts into a model improves its performance. Specifically, we examine the difference between simulations that use only 'far-field' glaciological stresses associated with ice shelf geometry and boundary conditions and simulations that embody both the far-field and the near-field effects of the rifts themselves. Real-world Ross Ice Shelf rifts and observational data sets are used for this purpose.

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Terdiurnal tide rocks the Ekstroem Ice Shelf, Antarctica

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The floating ice shelves surrounding Antarctica stabilize the Antarctic ice sheet and link its ice masses to the dynamic ocean system. The periodic changes of the ocean tides force ice shelf dynamics, influence ice stream velocities, and therefore affect ice mass balance. GPS observations can directly measure changes in ice velocities, but internal causative processes within the ice body remain hidden. However, seismological measurements of ground motion reveal the stress state of ice bodies and hence can give clues about internal ice dynamics.

We analyzed seismological data from Neumayer Station III, Dronning Maud Land in East Antarctica, and calculated spectral noise levels using probability power spectral densities. The noise levels in the frequency range of 1-10 Hz change periodically with the ocean tides, but additionally to the major diurnal and semi-diurnal tidal constituents, we observe a strong terdiurnal component (8 hour period) in the noise levels reaching the same magnitude as semi-diurnal noise changes, although the amplitude of the exciting terdiurnal tide is only about a tenth of the semidiurnal amplitude. We speculate that a geometric resonance in shallow cavities near the grounding line might amplify the terdiurnal tide and reduce basal drag. Consequently the ice stream velocity increases and higher stress release leads to the observed elevated noise levels.

Linked ice shelf–ocean models therefore underestimate the influence of the terdiurnal tide and require additional processes to explain the strong effect it has on noise levels in seismological data and on the stress-state of the ice body.

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Present and past evolution of Fimbul Ice Shelf region, East Antarctica: Ground-based investigations over three ice rises

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Ice rises are locally grounded features surrounded by floating ice shelves. They help regulate the outflow of ice from the Antarctic Ice Sheet, while holding past climate information within their ice stratigraphy. We investigate the present and past evolution of three ice rises located within Fimbul Ice Shelf in Dronning Maud Land, East Antarctica. These ice rises are within ~200 km of each other but differ in their settings within the ice shelf. Investigating their evolution thus allows extracting insights into the dynamics of this region and ice-rise evolution. We use ground-based geophysical measurements including static and kinematic GNSS, firn cores and ice-penetrating radars to determine their glaciological settings including surface and bed topography and surface flow speeds. Surface mass balance estimates show strong upwind-downwind contrast, a sign of orographic precipitation on all the ice rises. Mass balance using Input-Output Method show Blåskimen Island to be thickening at ~0.3 mi.e. yr-1 while initial estimates from other two ice rises show Kupol Moskovskij to be thickening (~0.4 mi.e. yr-1) and Kupol Ciolkovskogo close to balance (~0.1 mi.e. yr-1). Presence of distinct englacial features in the ice stratigraphy suggests stable divide positions for at least 500—1100 years for the three ice rises. To investigate longer-term evolution, we apply a thermo-mechanically coupled Elmer/ICE model to profiles going across these ice rises and constrain the model results with present-day flow speeds and englacial stratigraphy. Here we present a synthesis of our results and discuss the emerging picture of the dynamics of this region.

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Mapping coastal ice in Victoria Land by interferometric SAR and laser altimetry

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The Victoria Land coast is a unique environment containing a mixture of open water, floating ice tongues, icebergs, sea ice and landfast ice. The abundance and variability of the ice attached to the Antarctic coast is a consequence of oceanic, atmospheric, and glaciological processes, including coastal currents, ice shelf melting and supercooling and wind patterns. Our hypothesis is that the stability of ice tongues is a result of such interactions. In this study we investigate seasonal patterns in fast ice and relate these to ice tongue dynamics. In order to establish such a relationship a time series of landfast ice extent and deformation is assessed.

We map fast ice extent over regions of the Victoria Land Coast in the Western Ross Sea, from 2017 to 2019 using SAR interferometry. This method has been successfully tested in the Arctic (e.g. Dammann et al., 2019) for fast ice with relatively small deformation and showing strong radar phase coherence. We use Sentinel -1 in image (IW) mode with a 12 day repeat pass orbit image pairs. Sentinel-1 has been in operation since 2016 enabling the development of a 4 year InSAR time series showing fast ice extent and deformational patterns. In addition, ICESat-2 elevation data reveal freeboard and allow estimation of fast ice thickness. We present preliminary results of how fast ice deformation is related to its thickness. By extending the InSAR time series the next steps will be to establish a relationship between ice tongue dynamics and landfast ice morphology.

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Regional modelling of the atmosphere, ocean and ice sheets over Antarctica and the Southern Ocean

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The climate dynamics at high southern latitudes is controlled by strong interactions between the atmosphere, the ocean and the ice sheets. In order to study the role of those exchanges in the variability and the predictability of the system, a new regional model is currently developed. The configuration covering the Southern Ocean south of 30°S is based on the atmospheric model COSMO-CLM, the sea ice ocean model NEMO-LIM and the ice sheet model f.ETISh. The distribution of key variables such as sea ice extent, wind stress and simulated fluxes at the ice shelves base are evaluated in a 1-year simulation with the model by a comparison with observations as well as with the results of multi-decadal uncoupled or partly coupled simulations (in particular with the coupled ocean ice-sheet model). The goal is to describe the main biases and identify their origin in order to reduce them in the forthcoming simulations with this fully coupled regional model.

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Acceleration of ocean-driven glacial melt in Amundsen Sea Embayment, West Antarctica, measured using stable seawater isotopes

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The West Antarctic Ice Sheet (WAIS) contains enough water to increase global sea level by 3.3m. 200,000km² of WAIS are drained by the fast-melting Pine Island Glacier via a floating terminus into Pine Island Bay, in the Amundsen Sea Embayment. The mass balance of West Antarctica is dominated by dynamic losses in the Amundsen Sea Embayment, where glaciers are grounded on reverse-sloping beds, as deep as 2500m below sea level. This mass loss is mostly driven by basal melting, where warm subsurface circumpolar deep water (CDW) comes into contact with ice shelves at grounding zones. Remote sensing techniques approximate mass loss based on elevation timeseries, but cannot account for losses via calving, or subglacial meltwater rivers flowing into the ocean. Here, we present a timeseries of meltwater measurements using 670 paired stable isotopes-salinity samples from Pine Island Bay during Austral summer in 2007, 2009, 2014, and 2019. Glacial ice is extremely depleted in two stable isotopes - δ18O and δD – these isotopes can be used, along with salinity, to calculate the fraction of glacial meltwater in coastal seas from all meltwater sources. This method directly measures meltwater presence, and is completely independent of other methods used to estimate melt. Measuring salinity and stable isotopes, a 40% increase in meltwater measured over the observation period, indicating an acceleration of melt by glaciers terminating in the Amundsen Sea Embayment, with implications for global sea level rise.

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On the Link between the Southern Ocean Fronts and Antarctic Ice Shelves Thinning

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Improving our knowledge of ice shelf–ocean interactions is a critical step toward reducing uncertainty in future sea level rise projections. It is now evident that ocean–driven basal melt is the major cause of ice loss from Antarctica's fringing ice shelves. However much of the fundamental dynamics of how the ocean delivers heat to the ice shelves remains unresolved.
Progress in this area requires bringing together the fields of ice shelf–ocean interactions and large–scale Southern Ocean oceanography. One way forward is constraining the contribution of changes in Southern Ocean circulation to the recent acceleration in Antarctic Ice Sheet mass loss. Using a combination of data sets (altimetry, hydrography and ice shelf thinning estimates), we document the variability of the CDW properties (upwelling location, temperature and salinity) and its link to Antarctic ice shelves' thinning rates. Observations show that changes in the thermohaline properties of CDW over the last 20 years are consistent with a southward shift of warm CDW towards the Antarctic continent. Our results also show that the areas where CDW upwells closer to the continental break coincide with the regions where Antarctic ice shelves are melting the fastest, especially in East Antarctica. East Antarctica has long been thought to be a stable part of Antarctica. However, our results suggest East Antarctica is more vulnerable to ocean forcing changes than previously thought.

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Automatically Extracted Antarctic Coastline Using Remotely-Sensed Data: An Update

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The temporal and spatial variability of the Antarctic coastline is a clear indicator of change in extent and mass balance of ice sheets and shelves. In this study, the Canny edge detector was utilized to automatically extract high-resolution information of the Antarctic coastline for 2005, 2010, and 2017, based on optical and microwave satellite data. Visual comparisons have been conducted, and the accuracy of planimetric position of automated extraction is better than two pixels of Landsat images (30 m resolution). Our study shows that the percentage of deviation (<100 m) between automatically and manually extracted coastlines in nine areas around the Antarctica is 92.32%, and the mean deviation is 38.15 m. Our results reveal that the length of coastline around Antarctica increased from 35,114 km in 2005 to 35,281 km in 2010, and again to 35,672 km in 2017. Meanwhile, the total area of the Antarctica varied slightly from 1.3618 × 107 km2 (2005) to 1.3537 × 107 km2 (2010) and 1.3657 × 107 km2 (2017).The results indicated that the decline of the Antarctic area between 2005 and 2010 is related to the breakup of some individual ice shelves, mainly in the Antarctic Peninsula and off East Antarctica. We present a detailed analysis of the temporal and spatial change of coastline and area change for the six ice shelves that exhibited the largest change in the last decade. The largest area change (a loss of 4836 km2) occurred at the Wilkins Ice Shelf between 2005 and 2010.

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Beryllium isotope fractionation in Antarctic marine sediments

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Be isotopes from the authigenic phase of Antarctic marine sediment are being applied to understand past and present ice shelf and ice sheet dynamics. However, the geochemical behavior, sourcing and transport pathways of Be isotopes, namely ^{9}Be and meteoric ^{10}Be, in the Antarctic marine environment is still poorly understood, making the interpretation of isotopic concentrations and ratios with respect to paleoenvironmental and paleoclimate changes in sediment archives challenging. Further, geochemical extraction procedures for Be isotopes within the authigenic phase is complex due to its affinity to different minerals with variable degrees of binding strength. In open ocean, coastal or temperate riverine environments several chemical leaching procedures have been proven to be reproducible and conservative, however they have yet to be validated in polar regions. We apply a range of single and sequential extraction procedures on marine sediments from the front of the Amery Ice Shelf to ascertain the chemical phases that Be isotopes are associated with. We find that, as in the previous studies, both ^{9}Be and ^{10}Be are primarily associated with the labile oxide phases. However, unlike more temperate regions, $^{10}Be/^{9}Be$ ratios vary with strength of the extraction technique applied, and the amount of Fe and Mn oxide phases dissolved. Comparing the different extraction techniques has provided an opportunity to assess their efficiency in targeting different Be bearing phases, which will aid in our ability to selectively extract the authigenic Be isotopes, while avoiding the component which may have been delivered in reworked basal sediments of terrigenous origin.

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Responses of Antarctic melting to the future climate forcings

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The impact of forcings from CMIP5 CGCMs on the future projections of regional ice sheet melting and sea level rise produced by ice sheet model is investigated. The 2-dimensional (2-D) shallow shelf approximation model (MacAyeal, 1989), which is implemented in the Ice Sheet System model (ISSM) (Larour et al., 2012) is used. The historical runs and future projections forced by changes in atmospheric and oceanic forcings based on IPCC RCP(Representative Concentration Pathway) scenarios from climate models are carried out. From 1950 to 2100, ensemble experiments with atmospheric forcing-only, oceanic-forcing only, and all forcings from RCP2.6, RCP4.5, RCP6.0 and RCP 8.5 scenarios are conducted, respectively, to investigate the relative impact of forcings. The changes in ice velocity and ice thickness are analyzed and relative impacts of atmospheric and oceanic forcings on future changes are estimated. The global and regional implication of these changes are also investigated.

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Airborne and ground-based geophysical evaluation of the englacial hydrological system near the grounding zone of the Sørsdal Glacier, East Antarctica

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Large swathes of the margin of the East Antarctic Ice Sheet experience surface melting during the austral summer. The nature and temporal evolution of the englacial hydrological system is poorly known, however, as are its potential connections with subglacial water systems and their effects on ice dynamics. We acquired helicopter-borne and surface-based ground-penetrating radar (GPR), broadband and high-frequency passive seismic and electrical self-potential (SP) data to delineate the geometry and monitor the temporal evolution of the englacial hydrological system near the grounding zone of the marine-terminating Sørsdal Glacier, Princess Elizabeth Land, East Antarctica. Our data, acquired between the austral summers of 2016-17 and 2018-19, reveal the presence of shallow englacial drainage structures interconnected with several surface lakes and with each other over minimum englacial distances of several kilometres. This englacial hydrological system, likely confined to within ~ 20 m of the glacier surface, surprisingly appears to be active not only through the austral summer but also throughout the Antarctic winter. Here we discuss the system's spatial and temporal drainage characteristics and their inferred forcing by meteorological effects and ocean-tide impacted ice dynamics. Our observations and inferences have important implications for the volume and timing of meltwater runoff and contribution to the surface mass balance of East Antarctica's ice margins.

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Interannual-to-multidecadal responses of Antarctic ice shelf-ocean interaction and coastal water masses during the 20th century and the early 21st century to dynamic and thermodynamic forcing

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Much attention has been paid to ocean-cryosphere interactions over the Southern Ocean. Basal melting of Antarctic ice shelves has been reported to be the primary ablation process for the Antarctic ice sheets. Warm waters on the continental shelf, such as Circumpolar Deep Water (CDW) across the shelf break and Antarctic Surface Water (AASW) warmed up in summer, play a critical role in active ice shelf basal melting. However, the temporal evolution and mechanisms of the basal melting and warm water intrusions throughout the 20th century and the early 21st century have not been rigorously examined and are not fully understood. Here, we conduct a numerical experiment of an ocean-sea ice-ice shelf model forced with a century-long atmospheric reanalysis for the period 1900–2010 to examine the interannual-to-multidecadal variability in the Antarctic ice shelf basal melting and the role of coastal water masses. The modeled Antarctic ice shelf basal melting has gradually increased about 1.5-fold from 700 Gt/yr to 1100 Gt/yr over the study period. A series of numerical experiments demonstrate that changes in wind stress over the Southern Ocean drive enhanced poleward heat transport by stronger subpolar gyres and reduce coastal sea-ice and cold-water formations, both of which result in an increased ocean heat flux into Antarctic ice shelf cavities. Furthermore, an increase of sea-ice free days leads to enhanced regional AASW contribution to the basal melting. This study demonstrates that changes in Antarctic coastal water masses are key metrics for better understanding of the ocean-cryosphere interaction over the Southern Ocean.

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40 Years of Föhn Wind-Induced Melt on the Antarctic Peninsula from 1979-2018

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Warm and dry föhn winds on the lee side of the Antarctic Peninsula (AP) mountain range cause surface melt that can destabilize vulnerable ice shelves. Topographic funneling of these downslope winds through mountain passes and canyons can produce localized wind-induced melt that is difficult to quantify without direct measurements. Our Föhn Detection Algorithm (FonDA) identifies the surface föhn signature that causes melt using data from twelve Automatic Weather Stations on the AP and uses machine learning to detect föhn in 5km Regional Atmospheric Climate Model 2 (RACMO2.3p2) output and in the ERA5 reanalysis. We estimate the climatology and impact of föhns that cause surface melt on the AP surface energy budget, surface melt pattern, and melt quantity from 1979-2018. We show that föhn-induced melt is strongest at the eastern base of the AP and the northern portion of the Larsen C ice shelf, and can occur on the Ronne ice shelf, farther south than any previous research has indicated. We identify previously unknown wind-induced melt possibly katabatic in nature on the Wilkins and George VI ice shelves. The observed warming and associated southward shift of westerly winds on the AP suggest the possibility of concomitant increases in wind-induced melt. Interestingly, neither RACMO2 nor ERA5 datasets exhibit a significant increase in föhn melt over the past 40 years.

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Icefin observes super cooling and marine ice accretion in a basal crevasse beneath Ross Ice Shelf

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In December 2019 we deployed the remotely operated underwater vehicle (ROV) Icefin 3-4 km seaward of Ross Ice Shelf grounding zone. During our final mission we drove into a 50 m tall basal crevasse and found a transition from melting meteoric ice to accreting marine ice from the base to the top. The accreted ice demonstrated a vertical gradient of crystalline textures and color, and the surrounding waters in the top 10 m of the crevasse were supercooled. We interpret this to be evidence of in situ ice pumping with implications for ice-ocean interactions, shelf stability, radar interpretation, and ecosystem processes.

In total, we completed 5 km of survey transects over three missions in the 30 m thick ocean cavity below 585 m of ice at Kamb Ice Stream grounding zone. We also observed a stratified water column with maximum thermal driving of +0.3°C, melting meteoric and sediment-laden accreted ice, five 40-50 m tall crevasses over a 1.5 km along-flow transect, and possible sediment wedges on the seafloor. ROV Icefin was developed in the Planetary Habitability and Technology lab (Meister et al., 2018) specifically for borehole and under-ice deployments and carries multiple sonars, cameras, and biogeochemical sensors. The observations presented here are the result of collaboration with NZ Antarctic Science Platform and the NZARI Ross Ice Shelf Programme at KIS-1 camp.

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On the Tidal Currents Observed by Moorings in Prydz Bay, East Antarctica

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We firstly report on mooring observations of tidal currents in Prydz Bay, East Antarctica. The observed tidal currents are mixed diurnal-semidiurnal, with the spatial and temporal averaged value of 2.58 cm s-1 for all the current meter observations over the continental shelf. Probably steered by the topography, the major axes of the tidal ellipses are generally aligned south-north, and the tidal phases are modulated by both the baroclinic and barotropic tidal components. At the Amery Ice Shelf calving front, the averaged tidal kinetic energy can account for a fraction of ~13% with respect to the total kinetic energy during the observing period. Although the long-term average tidal heat flux across the Amery Ice Shelf front is negligible, the ratio of the tidal heat flux standard deviation to the residual heat flux standard deviation can be up to 41%. For better understanding the tidal influences on the Amery Ice Shelf basal mass balance, we also assessed the temperature and salinity records from six boreholes drilled through the Amery Ice Shelf. We identified tide-like pulsing from the potential temperature and salinity record from the sub-ice-shelf cavity, implying the remarkable tidal influences in the ice-ocean boundary layer. Both the mooring and borehole data support that the tidal processes should be highlighted in the investigations of the interaction between the Amery Ice Shelf and the ocean.

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Looking for water on a small Antarctic Peninsula ice shelf

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Over the last two decades, several ice shelves in the Antarctic Peninsula region have experienced significant volume loss or even total collapse driven by atmospheric, oceanic and hydrological processes. The underlying premise of this study is to understand the role of liquid water in the modification of the mechanical properties of ice shelves that may lead to destabilisation. This presentation will focus on the first stages of a wider field and modelling programme based on the Müller Ice Shelf in which we will present the stratigraphic characterisation of three ice cores, observations of the drainage system and the first steps towards drainage system modelling.

During the initial field campaign (February 2019), no liquid water was observed at the surface, however, during the drilling of the three firn cores, liquid water was present at all sites. The three cores where taken with an electrical drill, and two reached approximately 18 m depth, and the third 4 m. Depths where limited by the presence of completely saturated material which prevented further extraction. On analysis in the laboratory, the conductivity of the saturated sections was found to be equivalent to freshwater therein confirming the presence of aquifers within the firn. The prevalence of water and the characterization of the aquifers will provide a baseline for future dynamical studies using physically based models.

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A boundary layer framework to explore the physics of ice-ocean interactions

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Ocean-driven melting at the bottom of ice shelves is a primary cause of mass loss in present-day Antarctica. However, direct observations of the ice-ocean boundary remain sparse and challenging to date. This on one hand leads to a limited understanding of the physical processes at work at the ice-ocean interface, while on the other hand little consensus exists as to whether the parameterizations commonly employed in ice sheet simulation codes and ocean models are physically realistic. In this work we pursue a different approach, and seek to derive a self-consistent, first-principle model of the ice-ocean boundary layer. Building off an analogy with the planetary boundary layer, we construct a boundary layer model describing a buoyancy-driven current originated by the contact of warm ocean water with the ice shelf bottom, and its evolution along the shelf. Within this framework, we investigate two distinct regimes: the first one is alike katabatic layers in the atmosphere, with the key difference that adiabatic heating is here replaced by heat advection along the shelf; the second regime is an analogue to Ekman layers, with rotation effects playing a dominant role. We conclude by discussing the role of eddy viscosity closures, and particularly the importance of including the effects of stratification on turbulent mixing in models of the ice-ocean boundary layer.

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Low precipitation and high temperature recorded in Bahía del Diablo glacier, Antarctic Peninsula

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During the period 2015-2019 annual precipitation observed in Bahía del Diablo Glacier, northeastern Antarctic Peninsula, was very low compared with previous years (2003-2014). Annual water equivalent precipitation measurements at sea level and at 650 m a.s.l. are obtained every year in the nearby area of the glacier. An automatic weather station also nearby the glacier recorded high mean air summer temperatures during this period. In consequence, both effects led to a very negative mass balances for Bahía del Diablo glacier after having a series of positive or near zero mass balances. Precipitation nearby the glacier was ~150 mm w. e. less than the mean during the previous period of 12 years. At sea level the precipitation recorded was ~50% of the previous period, while at 650 m a.s.l. the recorded value was ~70%. This pattern of low precipitation was also recorded in the region at Marambio Station, where similar devices to the installed in Bahía del Diablo glacier were used to measure the annual precipitation. In particular, air temperature was high during January and February 2020 and the record of temperature of 18.3°C was recorded in Esperanza Station, near Bahía del Diablo glacier. This led to have very wet snow and surface rivers on the glacier surface, even at more than 500 m a.s.l, where usually there is only snow.

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Surf's up! Sea Ice Loss and Ocean Swell as a Trigger for Antarctic Ice Shelf Disintegrations

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Understanding the causes of catastrophic recent disintegrations of Antarctic ice shelves (Larsen A and B and Wilkins) is crucial to improving models of the Antarctic ice-sheet system and assessing the vulnerability of remaining ice shelves to environmental change. This in turn is a key step to enabling more accurate prediction of the future ice-sheet state and its contribution to sea-level rise. While progress has been made towards understanding melt-related and glaciological processes that precondition and weaken the shelves, the mechanisms responsible for triggering their disintegration have remained largely unknown. Here, we examine a climate-related causal factor and trigger mechanism that has been overlooked to date – namely regional sea-ice loss (both pack and fast ice). Based upon analysis of satellite, wave-hindcast and model-output data, we propose that increased seasonal absence of a protective sea-ice "buffer" offshore exposed the vulnerable outer ice-shelf margins to increased flexure by ocean swells. Over time, this weakened existing outer-margin crevasse and rift systems to the point of calving of elongated outer bergs, which precipitated abrupt and rapid runaway disintegration of the larger ice-shelf areas weakened (preconditioned) by combined surface flooding and hydrofracture, thinning and glaciological factors. These are "common essential prerequisites" for disintegration in the cases examined. The new findings highlight sea-ice change/variability as an important additional player affecting ice-shelf stability, depending on the region and ice shelf. They also underline the highly-coupled nature of the ice-shelf system undergoing change, and the need to better understand, quantify and model the sea ice-ice sheet interactions involved.

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India-Norway joint efforts to examine mass balance, dynamics, and climate of the central Dronning Maud Land coast, East Antarctica

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India-Norway joint project MADICE has conducted three field campaigns from Maitri Station to Nivlisen Ice Shelf and two promontory ice rises bounding the ice shelf. Radar and GNSS profiling revealed topographic characteristics and englacial ice stratigraphy. Both ice rises have distinct Raymond Arches, indicating sustained divide flow from ice rise's summits in the past few millennia. Three ice cores drilled at these summits were used to date radar reflectors in the top ~30 m and to map SMB over the past three decades. We found that regional climate models replicate SMB very well over the ice shelf, despite a large model-cell size (5-10 km). However, SMB over ice rises are hardly resolved with the models, probably due to complicated topography not well represented in the model. Phase-sensitive radar was used to measure vertical strain rates over ice rises and basal melting rates over the ice shelf. We found that the seasonality in basal melt rates near the calving front is caused by summer-warmed ocean surface water pushed by wind beneath the ice shelf front. A different melt regime was found further inland, where basal melt is much smaller, nearly uniform regardless of the season but largely correlated with tidal cycles. We are currently analyzing phase-sensitive radar data over ice rises to constrain flow law parameters so that Raymond Arches can be unequivocally interpreted using ice-flow models in terms of evolution of the ice rises, and eventually infer histories of regional mass balance.

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Highly temporally and spatially variable Antarctic Ice Discharge throughout the 21st century.

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It has been widely reported that ice discharge from the Antarctic Ice Sheet has increased over the preceding decades. The vast majority of these increases can be attributed to the ongoing destabilization of the Amundsen Sea sector in West Antarctica, with limited change in East Antarctica. However, much less attention has been focused on the temporal and spatial variations of ice discharge in Antarctica over the observational period.

In this study we combine existing velocity products to create 12 timestamped velocity mosaics between 1999 and 2018 to investigate both overall trends in ice discharge and the variability across the observational period. At an ice sheet scale we report a 50 GT yr^{1} increase in ice discharge in West Antarctica and no overall change in East Antarctica. However, at an individual catchment scale we observe considerable temporal and spatial variability. For West Antarctica, despite the overall increase in discharge clear periods of deceleration are observed in most individual catchments. In East Antarctica, despite overall consistency, 3-10% variations in ice discharge are observed at several major outlet glaciers (e.g. Denman, Totten, Frost, Cook, Matusevitch, Rennick). These variations in discharge are primarily controlled by the ocean, but are also strongly influenced by localized factors such as stochastic calving, fast ice induced calving events/advance, bed topography and pinning points; and in some cases resulting in opposing trends in neighbouring catchments. Improving our understanding the processes driving these short term variations will be important in improving the accuracy of future sea level contributions from Antarctica.

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Links between calving dynamics, ice velocity and grounding line retreat of Denman Glacier, East Antarctica 1962-2018

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Over the past two decades outlet glaciers in Wilkes Land, East Antarctica, have been thinning, losing mass and retreating. This has raised concerns over the future stability of some of its major outlets that drain the Aurora Subglacial Basin, such as Totten, Denman, Moscow University and Vanderford Glaciers. Their present-day grounding lines are close to retrograde bed-slopes and, furthermore, geological evidence indicates that they may have experienced substantial retreat under past warm climates, which are similar to those predicted in the near-future. After Totten, Denman Glacier, is thought to be the largest contributor to global sea level rise in East Antarctica. However, despite its importance there are few detailed observations of its recent dynamics. In this study, we use remote sensing observations to report on the changes in glacier velocity (1962-2018), calving dynamics (1962-2018) and groundling line position (1996-2018). This reveals a ~17% increase in velocity between 1972-74 and 2018, and a retreat of the grounding line between 1996 and 2018. We also observe significant differences between Denman's present-day calving regime (1985-present) compared to past calving activity (1940s – 1985). In addition, Denman's ice shelf has shifted a few kilometres westward and now makes significantly less contact with an eastern pinning point that may have previously exerted a buttressing effect. Using a numerical ice flow model (Úa), we simulate these observed changes to explore the drivers of the recent acceleration.

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Study of the Lange Glacier and the Impact Due to Climate Change in Admiralty Bay, King George Island, Antarctic Peninsula

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The Antarctic Peninsula and adjacent islands are areas where the greatest regional warming of the Southern Hemisphere has been identified. In order to characterize the implications of Southern warming, we selected the Lange Glacier (LG) on King George Island, to assess: 1) superficial temperature and glacier dynamic using data loggers installed in stakes; 2) water conditions by a bathymetric survey and 29 CTD stations in front of the LG; 3) glacier front (GF) using both bathymetric and a Digital-Elevation-Model (DEM) data; 4) GF velocity using movement stakes data; 5) change in GF position using DEM and historical data of width GF; and 6) the calving flux (QC). Our results showed that 85% of the temperatures were above the 0°C melting point (mean=5.0±5.2°C). The stakes showed an average ice loss of 9.3±1.3cm. The mean glacier movement registered by stakes was 8.8±1.5m in the southeast direction (0.40±0.70m/day). This movement was corroborated by Sentinel-1 satellite images (Offset Tracking=0.43±0.01m/day). Bathymetric survey recorded depths from 10 to 220m at the GF, which corresponds to ice thickness below sea level. External waters intrusion to the Lange bay was identified from the oceanographic stations. The external water is warmer than resident waters, destabilizing the water column through convection processes. Our findings together indicated a continuous glacier fusion that increases its dynamics due to the increase of temperature, with a contribution of freshwater to the Admiralty Bay. Systematic monitoring is required to establish the direct implications of the LG climate change and water contributions to sea-level rise.

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Sensitivity study of a Convective-melt parameterization into ROMS (Regional Ocean Modelling System)

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Recent laboratory-scale experiments and turbulence resolving numerical simulations have highlighted the importance of the convective processes on the ice-loss rate at the ice-ocean interface. Direct Numerical Simulations (DNS) and Large Eddy Simulations (LES) at the ice-ocean boundary indicated that, below a threshold ambient current the ice-ocean boundary layer is convectively driven and the meltrate is controlled by the thermal driving, rather than the strength of the ambient current. DNS under a sloping ice-interface have also shown that under such conditions, local stratification can suppress the turbulent transport at the ice-ocean interface (Mondal et al; 2019) and the future evolution of the ice-shelf is sensitive to the ice-shelf morphology. These results have been implemented into ROMS-MISOMIP as a modified ice-ocean scheme where a Heaviside function flips between convectively driven and shear driven melt parameterization, subjected to the ambient current. Sensitivity studies have been carried out over an idealized domain with varying thermal forcing as well as adding steps like ice-bathymetry. However, all the simulations generate unrealistic overturn-circulation inside the ice cavity and melting at the ice-interface effective controlled by the stronger shear leaving the convective melt parametrization obsolete. We speculate that an uncoupled sub-grid scale buoyancy forcing might create instabilities into the momentum field, followed by a faster transition into the velocity dependent melt-regime with higher ambient velocity.

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Sensitivity of the Amundsen Sea Embayment to changes in external forcings using automatic differentiation

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Thwaites and Pine Island Glacier have been changing dramatically over the past decades. There is broad agreement that the intrusion of warm water into sub-ice shelf cavities is the primary driver of these changes but it remains unclear where these ice shelves are most sensitive to melt, and whether other processes could cause further or more dramatic mass loss. Here, we analyze the sensitivity of two high-resolution ice sheet models (STREAMICE and ISSM) to changes in boundary conditions and external forcing. We rely on automatic differentiation to derive the sensitivity of the volume above floatation after 3 years of simulation to changes in ocean-induced melt, ice rate-factor, basal friction, and surface mass balance. The sensitivity maps highlight the regions that are most at risk to changes in any of these forcings at high-resolution. We find that changes in basal melt close to the grounding lines or along shear margins have a large impact on the final volume above floatation. The sensitivity of the model to basal friction is large close to the grounding line of Pine Island glacier but limited in other regions. If the sensitivity to changes in the rate factor is significant along the shear margins of Pine Island, it is close to zero over the margins of Thwaites glacier, which calls into question a hypothesis that is frequently invoked in the literature. This exercise highlights the regions that are most at risk to changes in external forcings, but also which process should be properly captured by models.

1556

The strengths and weaknesses of the Thwaites Eastern Ice Shelf

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The Thwaites Glacier is one of the fastest changing glaciers and is likely to be a large contributors to sea level rise in the next century. It is 120km wide at its grounding line. Two thirds of the glacier flows more than 6m/day into a tongue of ice that has undergone significant changes in the last two decades, including two major retreats in 2002 and 2012. The other third of the glacier flows at 2m/day into a relatively stable Eastern Ice Shelf, maintained by the buttressing from a linear bedrock ridge roughly 40km from the grounding zone. Despite relatively stability, this ice shelf is also undergoing important changes. It's collapse could trigger glacier acceleration resulting in marked sea level rise.

As part of the International Thwaites Glacier Collaboration, the TARSAN Project has collected and analyzed oceanographic and glaciological data to identify and assess the evolving strengths and weaknesses of the Thwaites Eastern Ice Shelf.

Here we discuss the first findings from our analysis. Weaknesses include shear zones and rifting induced by the loss of the ice tongue; migrating basal channels; high localized basal melt rates; advected crevassed zones; and multiple pathways for circumpolar deep water to enter the subglacial cavity. These weaknesses are countered by strengths including the lateral extent of the bedrock ridge providing buttressing; relatively uniform and crevasse-free central ice shelf with a cold-ice core; and high accumulation of snow. Despite these strengths, the ice shelf is on a trajectory to collapse; however, we cannot say how soon.

Setting up a regional ocean model of the Ross Sea with the MIT general circulation model: validation and preliminary results from a Last Glacial Maximum paleo run

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Little is known about the oceanic circulation below ice shelves, yet this is a key aspect to be studied to better constrain Antarctic ice sheet sensitivity to past and projected climatic changes. During the last deglaciation (last 20’000 years), the impact that ocean circulation had on ice sheets and vice-versa is poorly understood, and the Ross Sea region stands out as a key place to study the present and past West Antarctic Ice Sheet dynamics.
We use a regional implementation of the MIT general circulation model for the Ross Sea to address this knowledge gap. The MITgcm allows circulation within ice shelves cavities, however in current implementation ice shelf geometry is fixed during runtime. Validation on present-day conditions is performed against the high resolution ocean reanalysis Mercator GLORYS and available data from Italian moorings.
We present preliminary results from a paleo-control run of the Last Glacial Maximum (LGM, 21’000 yrs ago). This simulation consists of a equilibrium spinup run started at the LGM, forced with PMIP3 simulated climatologies and bounded by a simulated LGM Antarctic ice sheet. Simulated circulation is compared with available geological proxies, and we assess the impact on the circulation of a reduced Ross Ice Shelf cavity during a glacial state.

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Spatial pattern of surface mass balance over the last three decades in the central dronning Maud Land Coast, East Antarctica

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The coastal region of Dronning Maud Land (DML), East Antarctica, is characterized by a large number of small ice shelves bound by isle- and promontory-type ice rises and rumples. These distinct topographic settings can make individual regions behave differently under ongoing climate change. To fill the knowledge gap in the central DML coast, we have conducted three field campaigns during Antarctic austral summers from 2016 to 2019, under an Indo-Norwegian research project MADICE on Nivlisen ice shelf and its fringing ice rises (Djupranen and Leningradkollen). We conducted shallow ice-penetrating radar sounding to see ice/firn stratigraphy in the top 30 m. In total five radar reflectors (isochrones) were tracked over a 400 km line covering the entire ice shelf and two adjacent ice rises. These isochronous reflectors were dated using two ice cores taken at the ice rise summits, with which the surface mass balance (SMB) history over multi periods in the past three decades was retrieved. The spatial SMB patterns of the Nivlisen ice shelf stayed similar for all periods over the ice shelf, small SMB in the eastern inlet of the ice shelf, and large SMB in the western end of the ice shelf. However, this east-west contrast and consequently the regional-mean SMB varied between periods. The SMB patterns over the ice rises are time variable and more complicated.
Keywords: Antarctic ice shelf, ice rises, ground-penetrating radar, ice core, and surface mass balance.

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The SOOS Amundsen and Bellingshausen Sector Working Group: current infrastructure and future perspectives

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The Southern Ocean Observing System (SOOS) is a joint initiative of the Scientific Committee on Antarctic Research and the Scientific Committee on Oceanic Research. The Amundsen and Bellingshausen Sea regional working group (RWG) is part of the newly formed RWG Consortium. This RWG aims to discuss progress and ideas in the Amundsen and Bellingshausen Sea sector to improve the functioning, development, outputs and outcomes of research, policy and stakeholder groups.
We present the outcomes of the first RWG meeting in Incheon, Korea (May 2019), and outline the objectives and key priorities for the coming decade in the Amundsen & Bellingshausen Sea sector. The workshop successfully outlined key drivers of the region and documented the status of multidisciplinary observations in the Amundsen/Bellingshausen Sector. From this consensus, the RWG identified key observational gaps, regional priorities, and challenges which will be presented here. The RWG aims to further collate a list of upcoming/anticipated work in the region to promote collaborative opportunities and to enable regional-scale observing, using SOOS best practice for observing systems. We will present how the community can engage and participate with the Regional Working Group and encourage further growth for the Amundsen/Bellingshausen Sea sectors in the future.

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Observations of a large anticyclonic eddy west of Thwaites Ice Tongue

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We present here the first observations of a large (30km) anticyclonic eddy west of Thwaites Ice Tongue. The TARSAN hydrographic cruise (Jan-Mar 2019), as part of the International Thwaites Glacier Collaboration, collected CTD and velocity data across the open Amundsen Sea shelf. As part of this survey, we identified a clear eddy feature in the habitually ice-covered region between Thwaites and Crosson.

The survey identified that the eddy circulated in the opposite direction to what would have been expected based on the local coastal current and bathymetry. The ship collected several ADCP and CTD transects across this feature and deployed an autonomous underwater glider in the centre. We describe the density and velocity structure, as well as related biogeochemical properties, of this eddy. We suggest a mechanism for the existence of this feature related to deep circulation of modified circumpolar deep water in the bathymetric channels which deliver warm water to the base of the Amundsen Sea embayment glaciers.

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Change and variability in Antarctic coastal exposure (lack of sea ice offshore) since 1979

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Sea ice is a ubiquitous though seasonally-variable feature of the Antarctic coastal zone, where it interacts strongly with the floating ice sheet margins that are particularly vulnerable to changing ocean conditions (including warming). Indeed, there is also mounting evidence of potentially strong relationships between coastal sea ice distribution and the characteristics and stability of glacier tongues and ice shelves, suggesting that sea ice is an indirect (though poorly-understood) player in regulating sea-level rise (Nature, Massom et al., 2018). Here, we introduce and present findings from two complementary new algorithms designed to quantify broad-scale change and variability in Antarctic coastal exposure to more open-ocean conditions (lack of sea ice offshore), by exploiting the satellite passive microwave sea-ice concentration record dating back to 1979. These are: (1) an "Antarctic Coastal Exposure Index"; and (2) a more detailed “Coastal Exposure Length” method. Initial examination of temporal and spatial patterns of occurrence and trends for 1979-2017 shows that West Antarctic coastal regions are largely dominated by an increase in coastal exposure, particularly in the West Antarctic Peninsular region but also in the Amundsen Sea. In contrast, areas of increasing coastal exposure area confined to smaller pockets only in East Antarctica, with the general trend being towards decreasing coastal exposure. This is further characterised by a distinct westward progression around the region, largely in summer. The new algorithms and findings complement the more widely-used sea ice concentration, extent and seasonality time series and a new analysis on fast ice.

Quantification of a significant and persistent Ice Shelf Water plume in the Western Ross Sea

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The Victoria Land Coastal Current comprises a significant and consistent plume of Ice Shelf Water which is sourced within the Ross Ice Shelf cavity and flows northward through Western McMurdo Sound. Here we combine >1,800 full-depth CTD profiles collected over 40 years to define the spatial extent and physical characteristics of the plume at the end of winter – the period in which the vast majority of observations have been made. At the point that it exits the ice shelf cavity the plume is in-situ supercooled by up to 50 mK, with supercooling extinguished within ~100 km. From these data we estimate the rate of supercooling relief to new ice growth – onto either existing ice cover or crystals suspended in the flow – and the net freshwater flux to the Ross Sea. We examine possible sub-ice shelf pathways and processes of ice-ocean interaction to explain the observed characteristics, and hypothesise the ultimate source region of the meltwater. The three-dimensional structure indicated by the hydrography is in good agreement with recent spatial surveys of sub-ice platelet layer thickness and incorporated platelet ice. The general consistency of these combined indicators suggests little interannual variability of local circulation over the past four decades, despite long-term freshening and recent rebound of shelf water salinity in the Ross Sea.

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Preliminary analysis of ocean data from beneath Eastern Thwaites Ice Shelf

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As part of the International Thwaites Glacier Collaboration (ITGC) Thwaites - Amundsen Regional Survey and Network (TARSAN) project, two automated multi sensor stations were installed on the Eastern Thwaites Ice Shelf. The stations included an oceanographic instrumentation suite (CTDs, doppler current meters, and laser-stimulated fiber-optic thermal profiler, installed by hot-water drilling through the ice shelf into the ocean cavity below. Profiles of the ocean depth, salinity, and temperature indicate water characteristics consistent with Circumpolar Deep Water (CDW: 34.7 PSU, +1.05°C) for the lowest 200 meters of the 525 m water column, with a mixed layer above that is gradational between the CDW and so-called polar water. Doppler current motion indicates southwestward mean flow with eddies for the mixed layer, and slower less organized motion for the CDW layer. We compare the known regional ocean circulation and characteristics to present an observational ocean structure and circulation pattern.

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The Grounding Zone of Thwaites Glacier Explored by Icefin

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From January 9-12 2020, ROV Icefin conducted the first long range robotic exploration of the grounding zone of Thwaites Glacier, as part of the ITGC MELT project. Icefin, an underwater vehicle designed for borehole deployments, conducted 5 missions amassing over 15km of continuous data collection with ten sensors, including oceanographic sensors, imaging and bathymetric sonar. Missions extended seaward over 3.2km from the grounding zone where Icefin observed basal ice in a 0.5 m water column and seafloor contact.   Imagery and sonar revealed a diverse set of basal ice conditions with complex geometry, including a range of terraced features, smooth ablated surfaces, crevasses, sediment rich layers of varying kinds, as well as interspersed clear, accreted freshwater ice. The water column ranged from ~100m thick downstream that thinned to an average of 50m before quickly narrowing in the last ~500m towards the grounding zone. Ocean conditions varied from moderately well-mixed near the grounding zone to highly stratified near the ice base at seaward locations. Generally subdued seafloor topography ran roughly parallel to ice flow direction. Sediments along the sea floor ranged from fine grained downstream to course angular gravel near the grounding zone distributed between larger boulders, and accreted basal ice contained heavy sediment load, often size sorted. Moreover, we catalogued organisms from the seafloor to the ice-ocean interface, including ice-burrowing anemones. Overall, the emerging perspective is that topography along the ice-ocean interface evolves dramatically from the grounding zone, and is influenced by the type of ice present in a given region.

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Annual Ice velocity mapping and mass balance of Antarctic ice sheet

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The knowledge of the ice flow is crucial for improving our understandings of a wide range of glaciological mass fluxes including ice-sheet mass balance, glacier physics, and glacier flow instability. we present a methodology which can automatically calibrate, mosaic, and post-process Landsat images into displacement maps, resulting in the new data products quantify the Antarctic continent-wide and seamless ice velocity. Specifically, we have assembled over 250,000 displacement maps to generate Antarctic-wide annual mosaics of ice velocity maps from more than 80,000 Landsat 8 images acquired between December 2013 and April 2019. We estimated the mass discharge of the Antarctic ice sheet in ~2008, 2014, and 2015 using the Landsat ice velocity maps, interferometric synthetic aperture radar (InSAR)-derived ice velocity maps (~2008) available from prior studies, and ice thickness data. An increased mass discharge (53±14 Gt yr-1) was found in the East Indian Ocean sector since 2008, due to unexpected widespread glacial acceleration in Wilkes Land, East Antarctica, while the other five oceanic sectors did not show significant changes. However, present-day increased mass loss was found by previous studies predominantly in west Antarctica and the Antarctic Peninsula. The newly discovered increased mass loss in Wilkes Land suggests that ocean heat flux may already be influencing ice dynamics in the marine-based sector of East Antarctic ice sheet (EAIS). The marine-based sector could adversely be impacted by ongoing warming in the Southern Ocean, which may be conducive to destabilization.

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A spatio-temporal view of Western Ross Sea hydrography from the Ross Ice Shelf grounding line to the continental shelf-break

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The combined Ross Sea continental shelf and ice shelf cavity cross a latitudinal range from 85°S to 71°S. As well as normal oceanic complexities, oceanic flows through this domain encounter a range of unique processes such as polynya, sea ice growth and variability, the ice shelf-ocean interface and the mechanics of the cavity and grounding line. Due to the unique setting we must rely heavily on in situ observation to help with understanding and improved predictive capability. Here we synthesize recent hydrographic timeseries from a range of locations spanning from the Ross Ice Shelf cavity grounding line at around 83°S, though the cavity and cavity edge. Then we shift from cavity hydrography to polynya and coastal data and finally onto the continental shelf break. Much, but not all, of the data are contemporaneous and span more than a year. We compare this with existing hydrographic timeseries data on the Continental shelf. This allows identification of scales of cavity and continental shelf hydrography, seasonality and connectivity.

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The dynamic response of the Ross Ice Shelf to changes in pinning point configuration

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Ice rises and rumples, sites of localised ice shelf grounding, participate in shelf-wide mechanics by generating lateral and basal shear stresses. These stresses modify ice velocity and thickness, and in turn, may affect the dynamics of the grounding zone and tributary glaciers. The mechanics and dynamics of pinning point regulation of ice shelf flow are examined here with a case study on a collection of pinning points in the Ross Ice Shelf (RIS). A snap-shot force budget analysis of RIS pinning point mechanics provides context for a detailed examination of the ice shelf-ice stream system dynamics associated with the Shirase Coast Ice Rumples (SCIR) in the eastern RIS. A numerical model of RIS and tributary ice stream flow, with and without the SCIR, is used to quantify their contribution to resistive stresses in the system. This allows us to examine, in detail, how the pinning points modify stress budgets at the grounding line, the ways in which other sources of flow resistance can accommodate the loss of a pinning point, and some perhaps less intuitive effects associated with thickness gradients across the floating ice shelf. We find, for example, that MacAyeal Ice Stream located directly upstream of the SCIR is less responsive to the loss of the ice rumples than the obliquely oriented Bindschadler Ice Stream. These, and other, somewhat subtle effects in the coupled mass and momentum balances are, we argue, most easily revealed using a case study approach.

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Bathymetry under Antarctic ice shelves - a decade of progress from Operation IceBridge

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Bathymetry beneath ice shelves has been an elusive parameter for understanding the ocean-ice interactions controlling ice shelf stability. Community compilations of Antarctic topography demonstrate significant progress in measurements of thickness of grounded ice and acoustic bathymetry mapping from ships in open water. The connecting regions, just offshore from the present day grounding zone remain difficult to access, and can be mapped directly from geographically limited surveys using submersibles or seismic methods, or indirectly from airborne surveys.

Substantial international efforts have undertaken airborne surveys of the gravity anomalies over ice shelves in order to model the underlying seafloor bathymetry. Here we present an overview of the contributions from the NASA mission Operation IceBridge. Aerogravity inversions for bathymetry have been a vital component of the mapping efforts of Operation IceBridge, a ten year NASA mission flying a suite of aerogeophysical instruments over both the Arctic and Antarctic. Operating from South America, McMurdo Station and Hobart, Tasmania, Operation IceBridge has collected gravity data from ice shelves around much of the circumference of Antarctica. Together with other international efforts, these data reveal how circum-Antarctic sub-ice bathymetry mapping has been transformed over the last decade.

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Influence of landfast sea ice on ocean-sea ice interactions in the area of the Totten Glacier, East Antarctica: a study with a high-resolution regional version of NEMO3.6-LIM3

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The Totten glacier drains over 570 000 km² of the East Antarctic ice sheet. Most of it comes from the Aurora Subglacial Basin and is marine based, making the region potentially vulnerable to rapid ice sheet collapse. Furthermore, over the past decade, the Totten glacier experienced net mass loss by surface lowering of its grounded part and thinning of its floating ice shelf. At broader temporal and spatial scales, understanding how changes in ocean circulation and thermodynamic properties are causing increased basal melt of Antarctic
ice shelves is crucial for predicting future sea level rise. In the context of the Belgian project PARAMOUR, we use a high resolution NEMO3.6-LIM3 regional model to investigate the climate's variability and predictability over the Totten area.

The focus here is on the role of landfast ice in the variability of the system. Landfast ice is sea ice that is fastened to either the coastline, the sea floor along shoals or grounded icebergs. Most sea ice models neglect or crudely represent the formation, maintenance and decay of coastal landfast ice. We parameterize landfast ice impact following the grounding scheme and tensile strength formulation of Lemieux et al. (2015, 2016), or by manually adding grounded icebergs over the continental shelf.

Those parametrizations are evaluated by comparing the simulated and observed extent of landfast ice. The impact of those parametrizations on the location and amount of sea ice and on the ocean circulation is then investigated to quantify the influence of landfast ice in the Totten area.

1295

Observed melt rate variability at the Totten Glacier Ice Shelf, East Antarctica

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The Totten Glacier drains a significant portion of the East Antarctic Ice Sheet. Satellite records have shown that the glacier has undergone thickness and velocity temporal changes, however, the drivers of these changes remain to be understood. Recent oceanographic observations near the Totten Glacier Ice Shelf front have found a pathway for deep warm water to enter the ice shelf cavity and potentially reach the grounding line.
To further explore the ocean's potential on modulating the Totten Glacier dynamics behavior, we deployed several autonomous phase-sensitive radio-echo sounders (ApRES) across the ice shelf and monitored basal melt rates within ~20 km of the grounding line for two years. Our results show a large spatial melt rate variability despite of the relative proximity of the sites. A numerical ocean model is used to give an insight to the potential causes of the observed melt rate variability.

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Surface Melting in East Antarctica, a threat to ice sheet stability in a warming 21 Century climate!?

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Large parts of coastal East Antarctica show significant surface melting. The extend of melting varies from year to year. In some years, the surface of ice shelves like the Amery Ice Shelf is covered by kilometre long supra-glacial lakes. A supra-glacial hydrological network extends from upstream of the grounding line to the calving front. Supra-glacial meltwater in part refreezes at the surface and in crevasses at the end of summer and in part is draining into the ocean or the subglacial environment either in the form of rivers cascading across the calving front or through moulins into the sub-ice shelf cavity. Observed lake drainage events are in the order of a cubic kilometre, sufficient in size to have a significant impact on ice shelf cavity circulation and or subglacial drainage. Observations from the Antarctic Peninsula link supraglacial melting and melt ponding to ice shelf collapse and accelerated ice discharge through the removal of buttressing.
A review of the multidecadal record of supra-glacial melt distribution in East Antarctica with a focus on the Amery Ice Shelf is presented and its implication on Ice Sheet/Shelf Stability in a warming 21st Century Climate discussed.

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Pathways and modification of warm water flowing beneath Thwaites ice shelf, West Antarctica

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Thwaites Glacier is a vulnerable and rapidly changing outlet for the West Antarctic Ice Sheet. Here we present the first direct observations of ocean temperature, salinity, and oxygen underneath Thwaites ice shelf collected by an autonomous underwater vehicle. These new observations indicate that deep water (> 800 m) underneath the central part of the ice shelf is in connection with Pine Island Bay, which would be a previously unknown westward branch of warm deep water entering the ice shelf cavity. For the first time it is also shown that warm water enters from the north in two troughs separated by a pinning point. The easternmost of these troughs has southward flow from surface to bottom towards the ice shelf cavity, while the westernmost has a northward flow of comparatively fresh and cold water near the surface and more southward components in the denser and warmer water nearer the seabed. Intermediate water masses were identified as warm deep water found north of Thwaites ice shelf that has been in contact with glacial ice. Spatial gradients of salinity, temperature and oxygen recorded underneath the ice shelf indicate that this is a previously unknown active area where several water masses meet and mixes. The central buttressing point is identified as a vulnerable region of change currently under attack by warm water inflow from all sides: a scenario that may lead to ungrounding and retreat more quickly than previously expected.

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Bathymetry revised by hydrography observational data in Prydz Bay, East Antarctica

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Based on the International Bathymetric Chart of the Southern Ocean (IBCSO), we rebuilted an improved high resolution digital bathymetric model for the bathymetry of Prydz Bay and the surrounding region by compiling the water depths from in situ hydrography observations. After removing the reduplicated data from multiple data sets, we compared the water depths from the in situ hydrography observations with the seafloor depths from the IBCSO on the original IBCSO grid with a 500 m × 500 m spatial resolution. In the comparison, the data including multi-beam and single-beam echo soundings, digitized depths from nautical charts in IBCSO are fully preserved, and only the predicted bathymetry in IBCSO has been revised by the water depths from in situ hydrography observations with a specific gridding technique. Our bathymetry revision is mostly benefited by the observations from equipped seals, especially in the Amery depression. The improved digital bathymetric model can provide insights into the security of the voyages in Prydz Bay. In addition, by portraying an accurate seafloor around the continental shelf region, it favors our understanding of the dynamic and thermodynamic processes in the oceanic and sea ice circulation and the basal mass balance of the Amery Ice Shelf.

1720

Ice-ocean-ecosystem interactions influence CO2 uptake by a highly-productive coastal polynya

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Here we explore the potential impact of future climate-driven changes on the primary productivity and carbon dioxide (CO_2) uptake by Antarctica's greenest coastal polynya. With high primary productivity associated with the melting West Antarctic Ice Shelf, the Amundsen Sea Polynya (ASP) is a large sink for atmospheric CO_2 that is disproportionally important in its contribution to Southern Ocean air-sea CO_2 flux. Part of a classical high-nutrient/low-chlorophyl region, high productivity in these coastal seas may be explained partially by iron introduced from ice shelf melting, and the buoyancy-driven upwelling by the meltwater pump, but sea ice dynamics and winds are also important. Seasonal sea ice duration in the ASP is significantly reduced now compared to previous decades. High inter-annual variability in primary productivity suggests strong sensitivity to climate drivers. We explored how these physical drivers impact the coastal ecosystem using a 1-D numerical model developed for the ASP (Oliver et al. 2019). Model validation used the extensive observations from a field campaign in 2010-11 (ASPIRE; Yager et al., 2016). Productivity and carbon export were sensitive to potential future changes in sea ice cover, winds, and mixed layer depths. A continued decline of seasonal sea ice, increasing open water duration by up to 6 weeks, could lead to a reversal from net CO_2 uptake to net CO_2 outgassing for the ASP region.

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Modulation of shelf water by ice-ocean interactions in Terra Nova Bay polynya, Antarctica

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Terra Nova Bay polynya (TNBP), located in a coastal region of the Western Ross Sea, is a latent heat polynya formed by persistent katabatic winds blowing from the Nansen Ice Shelf. TNBP is considered as a key region of High-Salinity Shelf Water (HSSW) formation by polynya operation. There also occur vigorous ice shelf-ocean interactions, so the HSSW can be modulated by the influence of meltwater flowing from the sub-shelf cavity. The product of mixing between HSSW and the meltwater is identified as Terra Nova Bay Ice Shelf Water (TISW). In this presentation, we investigate spatio-temporal variations of the TISW (potential temperature < –1.93 ℃) using the hydrographic observations (CTD/LADCP and Glider) in TNBP during 2014–2019. The TISW was formed in January and has been developed (colder and less saline) from February to March with a supply of super-cooled plume flowing out from the cavity region under the Nansen Ice Shelf. The plume mainly pumps out at 400–700 m depths along the left-hand side of the deepest valley as affected by Coriolis force. In March, the TISW was also observed around 50 km east from the Nansen Ice Shelf. In comparison with the historical results, the TISW becomes much colder (~ 0.1 ℃) now and its main outflow region seems to move from the Campbell Ice Tongue to the center of the Nansen Ice Shelf. We also discuss about “How does the TISW influence to seawater properties in TNBP?” using a simple 1-D model.

SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 11

REMOTE SENSING OF THE POLAR REGIONS

Anna Hogg, Giorgiana De Franceschi
Nicolas Bergeot, Helen Fricker

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Glacier-Ocean Interface as an Important Mechanism in the Carbon Cycle: a case study from in situ measurements and remote sensing in Antarctica

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Recently glaciers and ice sheets have been recognized as hot spots for biogeochemical weathering with implications in the global carbon cycle (Bhatia et al., 2013; Hood et al., 2015; Wadham et al., 2019). Meltwater runoff contains significant amounts of dissolved and particulate organic carbon (DOC, POC) normally dominated by supraglacial melting (Stibal et al., 2012). Assessing both organic carbon (OC) reservoirs are important as they are likely to be influenced by different processes and to have positive and negative impacts on aquatic ecosystems (Musilova et al., 2017), as in ice sheets and glaciers (Hu et al., 2018). Although satellite data has been used to address the contribution of ice mass to the ocean, we still lack precise estimates of calving, melt runoff, and oceanographic properties to quantify accurately the release and impacts of DOC and POC in the marine ecosystems. Satellite and in situ data were collected in Lange glacier and Almirantazgo bay, King George Island during the summer of 2020 to quantify the glacial input of freshwater to the marine system. Three shallow ice cores were extracted to determine the concentrations per volume, as different features of DOC and POC. Moreover, an oceanographic transect and profiles were performed to assess OC characteristics, primary productivity, and bio-optical properties in terms of glacial influence. All the data collected is being analyzed and results will be presented during the framework of the SCAR Conference 2020.

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RESOURCE
Radio Sciences Research on AntarCtic AtmosphEre

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We report the application to establish a Programme Planning Group for developing a SCAR (Scientific Committee on Antarctic Research) Scientific Research Programme (SRP) entitled “Radio Sciences Research on AntarCtic AtmosphEre” (RESOURCE). The proposed SRP aims to gather the communities that investigate the polar atmosphere, with particular reference to Antarctica but with a bi-polar perspective, by means of radio probes into a common shared initiative. The scope is to improve the current understanding of the Antarctic atmosphere by sharing the expertise and the experience achieved by several scientific teams in the world, thus facilitating the advancement in the field and avoiding any duplication of activities already in action. SCAR is the best platform to create the necessary environment to assess the actual current understanding and to address the efforts to fill the gaps. The radio techniques enabled by ground and satellite-based sensors have proved to be very effective when probing the lower, middle and upper atmosphere. In parallel, several scientific communities using radio techniques spent significant efforts to remove (what they consider) “atmospheric noise” to extract the desired information from their measurements. However, these communities do not sufficiently interact. The RESOURCE SRP aims to take advantage of the experience of the SCAR Expert Group GRAPE (GNSS Research and Application for Polar Environment). The proposed SCAR scientific programme RESOURCE will build upon this important legacy by enhancing interactions between the scientists who measure and utilise the entire radio spectrum, either as an auxiliary or principal observation.

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Multi-scale mapping and monitoring of permafrost conditions in a high Arctic polar desert

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With the Arctic warming at twice the rate of the rest of the planet, permafrost landscapes are facing accelerated thawing and thermokarst (ground subsidence). In the face of this change, it is critical to monitor Arctic permafrost landscapes. However, the remoteness, inaccessibility, and vastness of Arctic sites can make high spatial and spectral resolution data collection difficult, and therefore mapping and monitoring problematic. To comprehensively evaluate the ground surface conditions in such environments, we propose a multi-scale remote sensing framework, combining medium and high resolution multi-spectral imagery (Landsat 7 and 8, Worldview 2 and 3) with high resolution unmanned aerial vehicle (UAV) RGB and thermal imagery, ground penetrating radar (GPR), and field observations. The derived surface conditions can be used as a proxy for changes in sub-surface conditions such as active layer depth or thermokarst. This framework was applied in the Eureka Sound Lowlands of Ellesmere Island, Nunavut to characterize permafrost conditions. Multispectral imagery was used to compute various vegetation and soil moisture indices (NDVI, SAVI, NDMI, TCB, TCG, TCW) over 20 years on a regional scale. UAV RGB and thermal images were used to create high resolution surface models using structure from motion on a local or landform scale, along with GPR and ground observation data to inform and validate the coarser satellite imagery analysis. Overall, the presented framework effectively bridges the gap between ground data collection, which is typically accurate, but limited in scope and satellite remote sensing, which covers large spatial extents, but is limited in accuracy.

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Investigating the seasonal dynamics of the Ross Ice Shelf, Antarctica using remote sensing data

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The Ross Ice Shelf (RIS) buttresses both the West Antarctic Ice Sheet (WAIS) and the East Antarctic Ice Sheet (EAIS) and thus has a strong potential to control future sea-level rise (Rignot et al. 2013). Understanding the processes that control RIS dynamics today can help interpret ice sheet changes due to atmospheric and oceanic warming that occurred in the past (Lowry et al. 2019) as well as what is projected for the future (Dinniman et al.2016).

This project aims to use remote sensing and fieldwork to better characterise short-term environmental variability in Ross Ice Shelf dynamics, because the sensitivity of the Antarctic Ice Sheet (AIS) system to internal environmental varaibility - as opposed to externally-forced large-scale climate perturbations - remains poorly understood and constrained (Gwyther et al. 2018; Holland et al. 2019). Remote sensing data can provide invaluable insights into Antarctica's ice flow rates and mass loss (Mouginot et al. 2017; Rignot et al. 2013), and this has led to improvements in ice sheet model initializations and parameter estimation (Pattyn et al. 2017). This presentation will present satellite and GPS ice velocity estimates for the RIS, and will compare these to observations of oceanic and atmospheric changes. Methodological as well as seasonal differences in ice velocity magnitudes will be discussed in the context of their ability to constrain ice sheet model simulations that explore how ice shelf behaviour may be influenced by short-term environmental forcing.

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Quantification of lateral stream channel migration on a basin-wide scale using lidar and Support Vector Machines: Taylor Valley, Antarctica

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The McMurdo Dry Valleys (MDV), are located adjacent to the Ross Sea and Transantarctic Mountains in East Antarctica. Nearly all of the precipitation (<100 mm/year.) in the MDV sublimates, while temperatures fluctuate above and below the melting point during austral summer producing irregular glacial runoff. Geomorphologic processes can therefore be seen as a function of regional climatic change. The MDV is remote, expensive to access, and too extensive to collect ample field data during the summer field season, making manual methods for migration tracking infeasible. An increase and then leveling off of solar radiation causes an increase in temperature in low albedo sediment and dirty glacial ice, resulting in mobilization of ice and sediment. Toolboxes for measuring migration are labor intensive and lack the capability of quantifying migration at a larger-scale. A toolbox for locating and quantifying lateral migration variability on a valley-wide scale was developed with the utilization of DEMs from both satellite and airborne derived lidar from 2001 to 2019. Geometric patterns of lateral change were used as input parameters to a support vector machine (SVM) for location of lateral migration. Additionally, climatic, topographic, and geologic controls on migration were assessed. This study evaluates and quantifies the stability of the MDV, which is projected to change at faster rates in upcoming decades due to regional climate change. This research will not only advance our understanding of channel geomorphology in the MDV but will also provide tools that will simplify locating lateral migration in larger-scale regions.

845

Recent glaciological mass balance of Znosko glacier, King George Island, Antarctic Peninsula

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Climate variations over the last decades show a strong warming trends in the atmospheric surface layer over the Antarctic Peninsula, concurrent with the glacial retreat, an increase in melt areas and disintegration of ice shelves. Little is known about glacier mass balance changes in this region because of the logistical difficulty involved, the large glacier areal extent and the extreme weather conditions the year around. This study present new glacier mass balance field data from Znosko glacier, King George Island, Antarctic Peninsula obtained by glaciological method, carried out in two field campaigns (austral summer 2018/19 and 2019/20) during the XXVI and XXVII Peruvian Antarctic Operation. The glacier has an estimated total area of 1.77 km^2 (January 2020), a length around of 1.9 km and maximum elevation of 300 meters above sea level (m.a.s.l.). 19 stakes were fixed on the glacier surface, in situ mass balance data were collected from yearly stake measurements. The glaciological observations reflects a heterogeneous pattern of accumulation and ablation areas, with an ELA of 124 (austral summer 2018/19) and 161 (austral summer 2019/20) meters above sea level (m.a.s.l.). Also, glacier surface digital elevation model (DEMs) were generated using UAV by photogrammetry method (Drone).

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Modelling glacier thickness distribution and bed topography of Znosko glacier, King George Island, Antarctic Peninsula

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The on-going drastic changes in the climatic systems have caused a substantial decline for the most glacier in the world. This phenomena has been observed at different locations on the Antarctic Peninsula and especially on King George Island. Ice thickness distribution and volume are important parameters for glaciological applications. The current study has been performed over Znosko glacier, King George Island, Antarctic Peninsula. The glacier has an estimated total area of 1.7 km², a length around of 1.9 km and maximum elevation of 300 meters above sea level (m.a.s.l.). We estimated the ice thickness distribution and bed topography for Znosko glacier using Glacier Bed Topography (GlabTop) model. We validated the model with ground penetrating radar (GPR) profiles and the glacier surface topography (DEM) obtained by photogrammetry method (Drone) with a sub metric resolution from two field campaigns carried out in the austral summer 2018/19 and 2019/20, during the XXVI and XXVII Peruvian Antarctic Operation, respectively. The results show that the ice thickness distribution varies at different parts in the tongue of the glacier, with a maximum value of 155 m at the central part. We bounded areas in the bedrock topography below sea level, which can be seen as potential sites for future lake formation.

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Airborne-validated satellite altimetry assessment of ice shelf-influenced fast ice

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The outflow of supercooled Ice Shelf Water from the McMurdo Ice Shelf cavity drives the formation of thicker land-fast sea ice and a sub-ice platelet layer in McMurdo Sound. Here, we investigated if the CryoSat-2 satellite radar altimeter is capable of detecting anomalously higher freeboard driven by the thicker ice shelf-influenced sea ice and the buoyant forcing of the sub-ice platelet layer beneath. CryoSat-2 ice freeboard obtained from Level 2 SAR interferometric surface elevation retrievals over fast ice in McMurdo Sound was compared with five years of drill hole measured sea ice and snow freeboard, and sea ice and SPL thicknesses, and snow layer depths in November 2011, 2013, 2016, 2017 and 2018. Trends of increasing CryoSat-2 obtained freeboard and ice thickness were observed with concurrent increases in sea ice and sub-ice platelet layer thickness towards the McMurdo Ice Shelf every year. The spatial distribution of anomalously higher CryoSat-2 derived ice freeboard correlated with the distribution of thicker ice shelf-influenced sea ice and the sub-ice platelet layer. Laser altimeter snow freeboard measurements from the ICESat-2 satellite altimeter and airborne electromagnetic induction surveys provided further validation to the CryoSat-2 observed freeboard anomalies over ice shelf-influenced fast ice. We demonstrated that the CryoSat-2 satellite radar altimeter is indeed capable of detecting freeboard anomalies driven by supercooled Ice Shelf Water outflow in McMurdo Sound, and is an applicable tool to identify regions of ice shelf-influenced fast ice elsewhere around the Antarctic coastline.

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Differentiating rock and ice in RGB and/or multispectral data

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In the high latitudes of the Polar Regions, deep shadows are a permanent presence. Consequently, the NDSI (Normalised Difference Snow Index) is ineffective in differentiating snow and ice from Earth observation imagery.

We present our past and continuing efforts to develop new methods to resolve this problem, including the fully automated multispectral method for mapping rock outcrop extent across Antarctica, and a new semi-automated method for mapping outcrop extent from RGB imagery.

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A lava lake in the South Sandwich Islands: Remote sensing of Mt. Michael, Saunders Island

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We show how Landsat and Sentinel multi-spectral satellite data was used to in the discovery of the world's fifth currently active lava lake.

Mt. Michael is an active stratovolcano on Saunders Island in the South Sandwich Islands volcanic arc. Previous analysis of satellite data from the 1990s suggested the existence of a lava lake inside Mt. Michael's crater, but the resolution was insufficient to prove the presence of a lake.

As in-situ observations of Mt. Michael are extremely difficult due to its remote location, dangerous surrounding sea and inhospitable surface, satellite data was used to monitor activity and detect thermal anomalies within the crater. We identified persistent volcanic eruptions and plumes throughout the thirty-year period studied. On five occasions in 2006 and 2018 a thermal anomaly within the crater was detected in shortwave infrared bands centred on 1.65 µm and 2.2 µm. Conversion of at-sensor radiance to land surface temperature using the Planck Equation estimated the pixel-integrated temperature of the lava lake at 233-427 °C. Further analysis using the well-established dual-band method estimated the molten lava to be radiating at 1040-1259 °C, assuming a cooler crustal lava of 200 °C. These observations suggest the lava lake is a permanent feature.

Associated publication:
Gray, D. M., Burton-Johnson, A. & Fretwell, P. (2020). Evidence for a lava lake on Mt Michael volcano, Saunders Island (South Sandwich Islands): Application of Landsat, Sentinel-2 and ASTER satellite imagery. Journal of Volcanology and Geothermal Research.

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Spatiotemporal evolution of the seasonal decay of snow albedo over Hurd Peninsula, Livingston Island, Antarctica, in the period 2000-2016.

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We have studied the correlation between topographic variables (altitude, slope, orientation, curvature, Topographic Roughness Index, Topographic Position Index, wind exposition and diurnal heating) and the seasonal albedo decay over Hurd Peninsula, Livingston Island, Antarctica from 2000 to 2016. We have used a Digital Terrain Model with a spatial resolution of 30 m. Snow albedo with a spatial resolution of 500 m was obtained from the MODIS (MOD10A1) daily snow albedo product. Only dates with a Sun Zenith Angle below 70° around midday are considered (September 1 to April 10 each season). The seasonal evolution of snow albedo was fitted to the exponential decay law $\alpha(t) = \alpha min+Aexp(-\beta t)$. For each pixel and each season we obtain: the albedo decay rate (β), the minimum albedo (αmin) and A. The albedo decay parameters exhibits a significant correlation with some topographic variables for certain seasons. We explored the influence of the air temperature and the surface temperature on the correlations found. The air temperature in autumn (March, April, May) and spring (September, October, November) determine the correlation between A and αmin and the topographic variables, while the air temperature in winter (June, July, August) and summer (December, January, February) determine the correlation between β and the topography. These results suggest that when the temperature gradient over the study area is small, the influence of topography on the snow albedo decay is not significant. This research has been funded by the Spanish Ministry of Science and Innovation (projects CTM2014-52021-R and CTM2017-84441-R).

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On site radiometric snow and bare soil patterns characterization to improve albedo estimation via satellite images for integration into glacier balance studies

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Radiometric response of snow albedo depends on snow properties such as density, hardness, water content, temperature and grain size, as well as on the impurities content. In addition, properties of bare soil such as color, texture and mineralogy are strongly related to albedo response of the surfaces. Due to this, the spatial and temporal variability of albedo distribution in polar areas is very high. During the 2017-18 and 2018-19 Spanish polar campaigns, we carried out several transects of distributed albedo measurements over Deception and Livingston Islands. In order to obtain the distributed measurements we devised a portable albedometer, consisting on two pyranometers, one facing the Earths's surface and the other facing the sky. Simultaneously to snow radiometric measures we performed snow pits. In addition, color of soils samples was characterized. For each sampled surface, the histograms of albedo were fitted to a normal distribution. Preliminary statistical analysis shows significant relations between snow properties, like grain size and water content, and albedo. On the other hand, soil color and texture showed to have a strong relation with albedo in bare soil areas. Recent results seem to indicate a slight increase in albedo in areas near Johnsons Glacier. It is necessary to characterize the albedo of the different surfaces in order to estimate the percentage of each one from orbital sensor data. This research has been funded by the Spanish Ministry of Science and Innovation (projects CTM2014-52021-R and CTM2017-84441-R)

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Interannual and Intra-annual Surface Velocity Variations at the Southern Grounding-Line of Amery Ice Shelf from 2014 to 2018

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The grounding line is the boundary indicating the transition from grounding ice to floating ice. The ice flow rate through the grounding line of the Amery Ice Shelf (AIS) is vital to understanding mass discharge received from three primary tributary glaciers into the ice shelf. This study investigated the interannual and intra-annual surface velocity variation along the southern segment of the AIS grounding-line from 2014 to 2018. Feature tracking was used to derive the surface velocity for five consecutive austral summer and winter seasons. Over the study period, AIS's southern end was observed a steadily ~ 5% annual increase of surface velocity since 2014. Two sharp surface velocity increases were observed in 2014/2015 (0.22 m/d) and in 2017/2018 (0.20 m/d) respectively. Moreover, an average interannual surface velocity increase of 16.45% and 12.11% exhibited at velocity peak in 2014/2015 and 2017/2018 respectively. The surface velocity of the winter season presents to be higher than the summer season every other year since 2015. The slowest flowing glacier in the study area, Fisher Glacier, exhibited the highest interannual increase (8.34%) and the largest intra-annual variation (5.58%) of surface velocity. This study offers new observations of surface velocity measurements on a yearly basis and detailed analysis of surface velocity variations. In addition, this study showed the capability of feature tracking to monitor the multidecadal changes of surface velocity from a limited number of observations of surface velocity, which is still undocumented in the AIS area.

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Characterization of gravity waves in the lower ionosphere using VLF observations at Brazilian Antarctic Station

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Here we present the investigation of the gravity waves (GWs) characteristics in the low ionosphere using very low frequency (VLF) radio signals. The spatial modulations produced by the GWs change the electron density at reflection height of the VLF signals, producing fluctuations of the electrical conductivity in the D-region, which are detected as variations in the amplitude of VLF signals. The analysis considered the VLF signal transmitted from the US Cutler/Marine (NAA) station that was received at Comandante Ferraz Brazilian Antarctic Station (EACF, 62.1o S, 58.4o W), with its great circle path crossing longitudinally the Drake Passage. The wave periods of the GWs are obtained using the wavelet analysis applied to the VLF amplitude, used as a new aspect for monitoring GW activity. The technique was validated comparing the wave characteristics of one GW event observed simultaneously with a co-located airglow all-sky imager both operating at EACF. The statistical analysis of the wave periods detected using VLF technique for 2007 showed that the GW events occurred all observed days, with the waves with period between 5 and 10 min dominating during night hours from May to September. During daytime hours the waves with period between 0 and 5 min are predominant all over the year and dominate all days from November to April. The results show that VLF technique is a powerful tool to obtain the characteristics of GW events, with the advantage to be independent of sky conditions, and can be used during all day and year-round.

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GeoMAP on REMA

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GeoMAP is a geological GIS dataset describing exposed bedrock and surficial geology of Antarctica. Recently constructed by a SCAR Action Group, v.202008 will be released at the Hobart OSC meeting. This poster illustrates the GeoMAP dataset draped over another recently released continent-wide dataset - the Reference Elevation Model of Antarctica (REMA).

GeoMAP comprises over 83,000 polygons that describe 'known geology' of rock exposures, rather than 'interpreted' sub-ice features. The map displayed here renders polygons with colours reflecting rock or deposit age, many of which are difficult to see at a continent scale. A rich attribute table enables data to be displayed or queried in a wide-variety of ways. Other data captured, but not displayed here, includes a source bibliography, fault lines and structural data. GeoMAP is primarily intended for continent-wide perspectives and cross-discipline science.

GeoMAP has been displayed over a shaded greyscale image of REMA relief, downscaled to 200 m resolution with data gaps filled by a 100 m DEM to provide visual continuity (Howat et al. 2019, The Cryosphere 13:665-674). REMA was constructed using the Blue Waters supercomputer and SETSM open source photogrammetry software. A series of individual DEM's were developed from DigitalGlobe optical stereoscopic satellite images acquired from 2009-2017, then registered vertically to satellite altimetry measurements from Cryosat-2 and ICEsat. REMA has absolute uncertainties of less than 1m over most of its area and relative uncertainties of decimetres. Version 1 was developed into a high resolution (8 m) terrain map covering ~98% of the Antarctic continental landmass.

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The effect of the diurnal cycle of surfactant-associated bacteria in the sea surface microlayer

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The upper 1 mm of the ocean's surface, the sea surface microlayer (SML), is occupied by a variety of organisms including bacterial genera capable of producing surface active agents (surfactants). Bacteria in the subsurface water (SSW) produce organic material containing surfactants, which accumulate in the SML. Surfactant accumulation forms sea surface slicks, which dampen short gravity-capillary waves. Surfactant-associated slicks are visible via synthetic aperture radar (SAR). Our current research is focused on the effect of UV exposure on the abundance of surfactant-associated bacteria within the SML and SSW. We have implemented the sampling approach described in detail in Parks et al. (IJRS Special Issue 2020). The in situ microlayer samples were collected in July-August 2018, November 2019 and January 2020 at two sites in the Straits of Florida (Looe Key and Fort Lauderdale) during RADARSAT-2 satellite overpasses. The DNA data was analyzed at the Argonne National Laboratory using the Illumina MiSeq. This data indicates a significant difference in the bacterial abundance between day and night in the SML. We hypothesize that the daily UV exposure of the SML results in a lower abundance of surfactant-associated bacteria sensitive to UV radiation. The diurnal variability of the surfactant-associated bacteria in the SML may affect the presence of sea surface slicks visible in airborne SAR. Assessing the microlayer in the Antarctic is particularly important because research is severely lacking on this environment, and this location is higly productive within the sea surface microlayer.

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Comparison of Sea Ice Detection Methods in the Atlantic Sector of the Southern Ocean

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Antarctic sea ice is characterized by extreme spatial and temporal variability. Remote sensing is a fundamental tool used in observing this variability, however, almost all satellite derived sea ice concentration detection methods have been developed for Arctic sea ice. In this study, different satellite processing algorithms have been compared against known sea ice conditions obtained during two cruises of the SA Agulhas II. The AMSR2 derived products used in this study included the Arctic radiation and turbulence interaction study Sea Ice (ASI), bootstrap (BST) and the Environment Canada's Ice Concentration Extractor (ECICE). This study shows that the traditional sea ice concentration-only based ASI and BST products are insufficient at describing important sea ice processes and mechanisms associated with short term sea ice variability. This was shown by considering two case studies, both of which investigated the effect of meteorological forcing on the Antarctic sea ice. The ASI and BST products showed the response of the 15% concentration ice-edge well, but failed to show any response in the ice interior. Conversely, the ECICE product showed substantial change at both the ice-edge and the ice interior. These processes show that both the ice-edge and ice interior are not only influenced by meteorological forcing, but also that these processes happen within daily timescales. Here it is argued that it is therefore necessary to further improve and validate ice detection methods for Antarctic sea ice, and that concentration-only based products do not sufficiently explain short term sea ice variability.

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Estimation of flow distribution of Shirase Glacier, East Antarctica derived from ERS-1/2 tandem mission SAR data

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Shirase Glacier is one of the fastest flowing ice streams in Antarctica with flowing speed of greater than 2 km/year (Nakamura et al., 2007, Aoyama et al., 2016). It is flowing into the southernmost of Lützow-Holm Bay in Dronning Maud Land, East Antarctica. It is important to clarify the spatial flow velocity distribution with a high-resolution to investigate causes of the fast flow and the temporal flow rate changes. We applied an interferometric Synthetic Aperture Radar (InSAR) technique to InSAR pair data acquired by European Satellite of Remote sensing (ERS)-1/2 during the tandem missions in 1996 and 1999.
We successfully obtained three SAR interferograms over Shirase Glacier from the tandem mission data pairs acquired at 1996/06/02-1996/06/03, 1999/11/14-1999/11/15 and 1999/12/19-1999/12/20. We estimated surface displacements along range direction (direction of radar illumination) by applying differential InSAR (DInSAR) with a TanDEM-X 90m DEM (Rizzoli et al., 2017) to remove topographic phase. We also estimated displacements along azimuth direction (direction perpendicular to range direction) by applying a split beam interferometry (SBI) (Bechor and Zebker, 2006) technique to the data pairs. We obtained flow velocity distributions by combining the range and azimuth displacements.
In the presentation, we will indicate accuracies of the obtained surface displacements as well as comparison with displacements derived from GNSS measurements on the Shirase Glacier. We will also discuss temporal changes in flow velocity and direction of the glacier.

1522

Nighttime Medium-scale traveling ionospheric disturbances observed by an All-Sky image at Antarctic Peninsula

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Medium-scale traveling ionospheric disturbances (MSTIDs) were observed in the red line emission, OI 630.0 nm, using an airglow all-sky imager at Comandante Ferraz Antarctica Station (62.1° S, 58.4° W; Magnetic Coordinates: 52.7 S, 10.9 E for 2015) between 2015 and 2016. These waves most occur during the winter and presented horizontal wavelengths between 75 and 200 km, observed periods mainly distributed between 10 and 50 min, and observed horizontal phase speeds range between 75 and 175 m/s. The waves showed a preferential propagation direction towards the Northwest. The most probable wave source could be associated with the Perkins instability mechanism. On the other hand, the Antarctica Peninsula is known as the source of strong tropospheric dynamics processes such as orographic forcing, cold fronts or strong cyclonic activity, that could be generating upward gravity waves that reach the thermosphere/ionosphere and thereby expanding the possibilities of sources to the MSTIDs. Furthermore, we are going to show the effects of magnetics storm above the Brazilian Antarctic station in the form of a stable auroral red arc.

1611

Continuing the satellite altimetry record over Antarctic ice shelves

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Antarctica's ice sheet is losing net mass to the ocean, and so are its fringing ice shelves. Although ice shelf mass loss does not directly lead to sea-level rise, it does lead to increased dynamic loss of grounded-ice mass because it reduces the back-stress ("buttressing") that ice shelves provide to the grounded ice. To fully understand how the ice sheet is changing overall, and predict how it will change in the future, it is crucial to quantify the rates of ice-shelf mass change and the relative contributions of the processes driving these changes. Since the early 1990's, satellite radar and laser altimetry has provided a long, continuous record of ice shelf height, allowing us to identify ice shelf responses to different drivers (ocean state, atmospheric state, and glaciological controls on grounded-ice flow and calving) which occur on a broad range of timescales. The current altimeter satellites (CryoSat-2 and ICESat-2) have extended the record to 2020, now covering all of the ice shelves, and allowing us to examine small-scale features related to critical mass-loss processes, e.g. rifts, basal channels, surface meltstreams and grounding zones. It is vital that we continue this sequence of polar-orbiting satellite altimeter missions so we have no gap in our ice shelf monitoring capability. Simultaneously, our community needs to develop a coordinated plan for acquiring in situ data for validating basal melt rate estimates derived from satellite altimetry, so we can improve our understanding of ice-shelf/ocean interactions all around Antarctica.

1592

Metamorphism of layered firn at Dome Fuji, East Antarctica: Evolution of relations between Near-infrared reflectivity and the other textural/chemical properties

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Evolution of polar firn was investigated at sites at Dome Fuji on the dome summit of East Antarctica, to better understand signals of both radio remote sensing data and deep ice cores. Using samples from a 4-m-deep pit and a 122-m-deep core, relations between major textural and chemical properties, such as Near-infrared light reflectivity R, density ρ, microwave dielectric anisotropy Δε, and concentration of major ions, were investigated at a depth range of 0 – 122 m, with high spatial resolutions. At the near-surface depths, we found: (i) Fluctuations of R, ρ, and Δε are positively correlated; (ii) Δε ranges 0.03 – 0.07 immediately below the snow surface at ~0.1 m depth; (iii) These properties of R, ρ, and Δε are not correlated to major ions. With increasing depths during reported phenomena of density crossover, the positive correlation of R to Δε persistently remains with a slight decrease. Besides, R becomes weakly negatively correlated to concentration of Na+ which is the sea salt marker. These facts suggest that textural features of the near-surface depths are preserved in both R and Δε at a depth range immediately below bubble-close-off, being weakly affected by reported softening of ice by Cl- ions. We therefore suggest that optically layered features in ice cores are directly linked to the metamorphism.

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Sea Ice Thickness and Snow Depth records from altimetry in Antarctica

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The main difficulties to retrieve Sea Ice Thickness (SIT) in Antarctica come from the lack of in-situ observation. For instance, whereas polar expeditions and in-situ observations over the Arctic have enabled to construct snow depth climatologies (e.g the Warren climatology), there is no equivalent data in the southern hemisphere. Then, except for a few studies (e.g Zwally et al, 2008 or Kurtz et al, 2012) based on ICESat, SIT estimations in Antarctica nearly remain nonexistent and no valid sea ice volume estimations have yet been drawn (SI-CCI-2015 report). In this presentation, we review our recent developments leading towards altimetric Sea Ice Thickness estimations in Antarctica.

First, we detail the methodology to derive sea ice freeboard from altimetric measurements and we present a 2002-2017 Envisat/Cryosat-2 sea ice freeboard time serie. The continuity between the 2 satellites is ensured by a recalibration of the Envisat Low Resolution Mode on the Cryosat SAR mode.
Thereafter, one of the most important obstacle to compute SIT is related to snow depth. Meanwhile, Guerreiro et al, 2016, has demonstrated the ability to retrieve snow depth from the combination of CryoSat-2 and Saral/AltiKa satellite data. Following this approach, we will present 2013-2019 bi-frequency altimetric snow depth estimations in Antarctica (computed within the ESA CryoSat + project). From these results, among the first SIT time series in Antarctica will be shown. Finally, we will explain how these data will be used for future climate studies such as sea level re-evaluation and the revisit of the freshwater budget.

1705

Influence of snowpack characteristics on TanDEM-X DEM - validation with REMA and field datasets acquired on the Ellsworth Mountains, Antarctica

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The penetration and interaction of X-band synthetic aperture radar (SAR) with snowpack depends on the snow layers physical characteristics related to snow accumulation processes. We use the new Reference Elevation Model of Antarctica (REMA) as a reference surface to subtract from the TanDEM-X elevation model (TDX) and evaluate the X-band interferometric bias in dry snowpack. We confirm the REMA's high accuracy with 70-km-long geodetic measurements on Union Glacier in the Ellsworth Mountains. A mean error of 1.01 ±0.61 meters was found. TDX presented a higher mean error of 2.05 ±2.37 m. We demonstrate that the TDX surface covaries with ice depth and accumulation layering changes in the GPR profiles. Furthermore, we propose that both DEMs' data can be used to investigate the subsurface feature changes and ultimately, the accumulation dynamic changes. Negative (positive) differences indicate high (low or negative) accumulation rate areas where deeper (shallower) penetration occurs.

332

Importance of blowing snow during cloudy conditions in East Antarctica: comparison of ground-based and space-borne retrievals over ice-shelf and mountain regions

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Continuous measurements of blowing snow are scarce, both in time and space, despite its importance in local and regional antarctic surface mass balance. Satellites now provide the opportunity to derive blowing snow occurrence, transport and sublimation rates over Antarctica. These continental-wide assessment of blowing snow are extremely valuable. However, little ground truth is available to validate these retrievals. In addition, optically-thick clouds block the penetration of the satellite signal , limiting blowing snow detection to clear-sky conditions.

The application of ceilometers for detection of blowing snow provide an opportunity to validate the satellite retrievals of blowing snow frequencies at two coastal sites in East Antarctica for the 2011-2016 time period. Thanks to their ground-based location, ceilometers are able to routinely detect blowing snow events in the presence of clouds and precipitation, which can be missed by the satellite. This is important, since the proportion of events missed by the CALIPSO and ICESat-2 satellites due to the presence of cloud decks is currently unknown. Over coastal areas, up to 90% of blowing snow occurs under cloudy conditions. In addition, differences in sensors limit the surface identification by the satellite, and the spatial in homogeneity of the blowing snow event can lead to events identified as blowing snow by the satellite but not by the ceilometer. These results indicate that while blowing snow transport and sublimation rates derived from satellite retrievals are a valuable product, further investigation is required to reduce uncertainties on coastal blowing snow occurrence.

1285

Assessment of East Antarctic sea-ice thickness during spring using ICESat-2, Operation IceBridge and in situ measurements

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The satellite records provides clear evidence of dramatic reduction of the annual maximum Antarctic sea-ice extent. However, little is known about concomitant changes in the ice structure including ice thickness. The dynamics nature of the Southern Ocean plus a generally thick snow cover result in a complex vertical layering of the sea ice, and its thickness is difficult to derive using remote-sensing techniques. To improve the translation of satellite information, and capitalizing on near-coindent data collection as part of NASA's Operation IceBridge [OIB], we collected a range of in situ sea-ice (and ice-sheet) measurements off East Antarctica during austral spring 2019. Here we anlyse a three-tiered dataset based on the ICESat2 laser profiles, OIB data from dual- colour laser altimeter, radars, as well as optical and thermal imagers and in situ transect measurements of sea-ice and snow thickness. The study was carried out on landfast ice, so that temporal offsets between measurements may be accounted using a column (thermodynamic) sea-ice model. We note locally very thick snow over the fast ice in late 2019, and explore its effect on ice thickness derived from total freeboard measurements.

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Mass Balance Constraints on Ice Sheets and Glaciers from Reflected GNSS Signals

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GNSS receivers are routinely deployed on ice sheets and glaciers to measure the speed of the ice surface. While the primary derived quantity from these geodetic receivers is three-dimensional position, signal power data (generally termed signal to noise ratio (SNR) data) are also recorded by the receiver. These SNR data can be used with the GNSS Interferometric-Reflectometry (GNSS-IR) technique to measure the vertical distance between the GNSS antenna phase center and the surface below. Because GNSS signals are transmitted at L-band and very low elevation angle data are used, there is very little penetration of the snow/ice surface. GNSS-IR measurements thus can provide a tight constraint on snow accumulation within a relatively large footprint (~1000-5000 m^2 for typical sites). Amplitudes of the reflection signals provide information about surface roughness and dielectric constant and thus can be used, for example, to examine surface melt. Examples will be given for 9-year records on the Greenland ice sheet as well as new GNSS reflection results from the Ross Ice Shelf, Thwaites, Kohler, Sorsdal, and Totten glaciers.

746

The anomalous sea ice conditions in McMurdo Sound during the winter of 2019

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The winter 2019 sea ice conditions in McMurdo Sound, Antarctica were affected by frequent and extensice landfast sea ice break-out events. This resulted in the unusually late formation of a stable landfast sea ice cover in the southern reaches of the Sound, which in turn affected winter / spring sea ice operations for the United States and New Zealand Antarctic programmes operating in the region. The greater than average number of break-out events were related to an increase in the number and intensity of southerly wind events in the region in the late spring / early winter period. Here we investigate the correlation between sea ice break-out events and southerly storms to elucidate this relationship. We first present the current understanding of the climatology of landfast sea ice in McMurdo Sound. We then characterise the 2019 winter sea ice cover using a combination of space-borne remote sensing products and sea ice mass balance station observations to quantify the nature and extent of the break-out events. Finally we compare these break-out events to the near-surface wind field and discuss how the southerly storms influenced the formation of landfast sea ice in the different regions of the Sound. An improved understanding of the way in which winter storms affect the landfast sea ice in McMurdo Sound has the potential to improve operational confidence in sea ice operations in McMurdo Sound during the late winter / spring period.

1503

DeepBedMap: Resolving the bed topography of Antarctica with a deep neural network

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To better resolve the bed elevation of Antarctica, we present DeepBedMap - a deep learning method that produces realistic Antarctic bed topography from multiple remote sensing data inputs. Our super-resolution deep convolutional neural network model is trained on scattered regions in Antarctica where high resolution (250 m) groundtruth bed elevation grids are available, and then used to generate high resolution bed topography in less well surveyed areas. DeepBedMap takes in a low resolution (1000 m) BEDMAP2 dataset alongside other high spatial resolution inputs such as ice surface elevation, velocity and snow accumulation to generate a four times upsampled (250 m) bed topography map even in the absence of ice-thickness data from direct seismic or ice-penetrating radar surveys. Our DeepBedMap model is based on an Enhanced Super Resolution Generative Adversarial Network architecture that is adapted to minimize per-pixel elevation errors while producing realistic topography. We show that DeepBedMap offers a more realistic topographic roughness profile compared to a standard bicubic interpolated BEDMAP2, and also run model inversions to compare the basal traction of our DeepBedMap_DEM with other bed elevation models.

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High spatiotemporal resolution land surface temperature for the Antarctic Dry Valleys

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The McMurdo Dry Valleys (MDV) are one of the few ice free areas on the Antarctic continent with biodiversity thriving on available liquid water. Accordingly, Land surface temperature (LST) is a critical variable influencing the terrestrial ecosystem. In an environment characterized by steep gradients in temperature, elevation, and availability of water and photosynthetic light, microorganisms largely depend on microclimates. Hence, to model the current habitat distribution, and predict possible changes induced by anthropogenic climate change, high spatial and temporal resolution LST data is indispensable.

As such data is currently unavailable for the MDV, this project aims at downscaling LST acquired by the MODIS sensor, which comes at a high temporal (sub-daily close to the poles) but low spatial (1000 m) resolution. High spatial resolution (30 m) information can be gained from the thermal channel of Landsat 8, which comes only at a low temporal resolution, though. Thus, MODIS LST is downscaled from 1km to 30m using Landsat 8 data as a reference. Land cover and terrain properties are used as additional high resolution predictors. Machine Learning models are applied to account for the complex relations between those variables. Training data are generated based on all temporally matching and cloud free scenes from 2013 to 2019. The trained model is applied to make predictions of 30m resolution LST for the entire MDV for all available MODIS scenes, i.e. from 2002 on.

The high resolution LST product will present a baseline dataset for subsequent ecological modelling of species distribution in the MDV.

1703

Investigating the magnitude of snow redistribution over the Antarctic Ice Sheet using ICESat-2, IceBridge, and atmospheric reanalysis data

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Snow that accumulates at the ice sheet surface is subject to redistribution (i.e., erosion or deposition) that is strongly dependent on the local topography and predominant wind direction and speed. Most atmospheric models do not account for these post-depositional processes; however, those that do can only resolve redistribution over large length scales (10s of kilometers) because of resolution restrictions. Improved understanding of snow redistribution will improve our interpretations of local mass balance as well as height changes derived from satellite altimeters (e.g., ICESat-2, CryoSat-2).
Here, we take a novel approach of combining fine resolution topography from NASA's next generation laser altimeter, ICESat-2, with patterns of small-scale snow accumulation variability from Operation IceBridge snow radar data to build a simple model of snow redistribution. Sensitivity tests suggest that the ideal resolution for studying snow redistribution is 1 kilometer, so we built a 1-km DEM over the entire grounded Antarctic Ice Sheet (AIS) using the first three orbital cycles of ICESat-2 (October 2018 – June 2019). In such a manner, we take advantage of the pointing bias early in the mission to fill in a denser grid. We next compare the curvature of this DEM with mapped snow accumulation variability and reanalysis wind speed and direction from MERRA-2 to build a statistical redistribution model. This model is next applied to the entire DEM, allowing us to quantify the spatial patterns as well as magnitude of snow redistribution over the entire grounded AIS.

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Spatiotemporal variations of snowmelt in Antarctica (1978–2019) derived from passive microwave radiometer data

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A Spectral Linear Mixing Model (SLMM) was applied for the snowmelt pixel estimation in passive microwave radiometer images covering the Antarctic continent. We used SMMR, SSMI and SSM/IS EASE-Grid calibrated data (25 km spatial resolution) and spectral signatures for the endmembers Wet Snow Zone (WSZ), Dry Snow Zone (DSZ) and Rock Outcrops (RO) to estimate daily Snowmelt Fraction Images (SFI) of Antarctica from 1978 to 2019. Each SFI pixel can have values from 0 to 1, that means a given snowmelt proportion (0 to 100%) in an area of 625 km2. To assess the accuracy of SFI images, we compared them with correspondent classified ENVISAT ASAR images (150 m) of the Antarctic Peninsula on 11 dates (2007 to 2009). The RMSE of the estimated SFI was lower than 0.06 for all dates, excepting for one with 0.29, pointing to low errors in general. The daily SFI data series was used to calculate the austral summer total and median area of snowmelt for seven different regions of Antarctica: Antarctic Peninsula, Filchner-Ronne Ice Shelf, Mary Bird Land, Ross Ice Shelf, Dronning Maud Land, Amery Ice Shelf and Wilkes Land. The spatiotemporal analysis of the estimated SFI images indicated that the most persistent and intensive melt in austral summer was observed on the Antarctic Peninsula, mainly on Larsen and Wilkins ice shelves. Other main regions with persistent and intensive melt were Mary Bird Land and Wilkes Land, followed by Dronning Maud Land, Amery Ice Shelf, Filchner-Ronne Ice Shelf and Ross Ice Shelf.

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Response of the southern polar ionosphere to CME and CIR driven storms

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In this paper, we studied the response of the high-mid latitude ionosphere during two geomagnetic storms driven respectively by Coronal Mass Ejection (CME) and Corotating Interaction Region using Global Positioning System (GPS) derived Total Electron Content (TEC) measurements. These storms occurred during the month of June 2015, when the southern polar region is bereft of solar radiation which is the main source of ionization. We observed large enhancements in the TEC during the main phase of the CME driven storm of 21 June 2015 as compared to the CIR driven storm that commenced on 8 June 2015. The factors that led to the observed ionospheric storm effects over the southern high-mid latitude ionosphere during both the storms are investigated using topside ionospheric measurements from the Defence Meteorological Satellite Program (DMSP) and NOAA/POES satellite measurements. We show that the TEC enhancements over the high latitude ionosphere are topside enhancements caused by the formation of the polar Tongue of Ionization (TOI). The topside enhancements in the TEC at the southern polar region are shown to be related to the appearance of positive ionospheric storms in the mid latitude regions. The role of stormtime electric fields and neutral winds in causing the ionospheric storm effects during both the storms are presented in detail. This study highlights the importance of the Solar wind-Magnetosphere-Ionosphere coupling in modulating the high latitude space weather during geomagnetic storms.

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Seasonal variations of snow height in Antarctica using GNSS Interferometric Reflectometry

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A reliable surface mass balance assessment is essential for a trustworthy Antarctic ice sheet total mass balance estimation. Snow accumulation is the primary ice sheet mass input, and is normally derived from satellite-borne altimetry, ice core studies or regional climate models, as in-situ data are scarce. By exploiting the GNSS Interferometric Reflectometry (GNSS-IR) technique, the current Antarctic GNSS antenna network can be used to retrieve local information on snow accumulation/ablation.
GNSS-IR uses signal-to-noise ratios (SNR) to sense the antenna near field environment. Reflected signals, usually considered as a detriment in positioning, are here turned into a source of information on the reflecting surface. The frequency of the SNR interference sinusoidal pattern depends on the vertical distance between the phase centre of the GNSS receiver antenna and the reflecting surface, and on the signal wavelength.
Applied to antennas in Antarctica, GNSS-IR allows to retrieve snow height variations, and to study snow precipitation/ablation in a meteorological sense. The homemade software ROB-IONO and Atomium are used to access the snow height variations at several GNSS stations. The first antenna considered has been deployed by the Royal Observatory of Belgium on the Derwael Ice Rise, in the coastal Dronning Maud land. This station provided continuous data from late 2012 to early 2016. Taking the antenna subsidence into account, we highlight an annual variation of snow accumulation in April-May (~30-50 cm) and ablation during spring/summer period. No long term trend is observed. Results from GNSS stations belonging to the POLENET network are also presented.

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The 3-dimensional structure of snowfall over Antarctica from remote-sensing observation and reanalyses

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Understanding atmospheric processes and variables in the polar regions is a key element of climate studies. In particular in Antarctica, precipitation is the single most important term controling te surface mass balance, but it is still not well known. The main challenges are the limited number of data and the measurement difficulties because instruments are not well adapted to the extreme weather conditions of this region.

In addition, the traditional 2D approach of precipitation (surface field) may not be sufficient to properly describe the microphysics and dynamics involved, in particular in the antarctic region where low-level atmospheric processes such as sublimation or blowing snow have a major impact on surface accumulation.

Fortunately, remote-sensing technologies have been deployed both on ground and in space. A precipitation radar at Dumont d'Urville station (Adélie lLand) and the Cloud Profiling Radar (CPR) on-board CloudSat which covers a wide part of the continent, – both have continously provided measurements over a large part of the atmospheric column both over 4 years. The latter made it possible to build the first 3D climatology of snowfall flux above the antarctic ice sheet (Lemonnier et al., 2019). Those two instruments are powerful source of information to assess the quality of atmospheric circulation models in this area – respectively at local and continental scale – and in particular reanalyses which suffer from a lack of observations there.

1274

Spatiotemporal variations in Antarctic ice mass revealed by GRACE and GRACE Follow-On

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This study presents a new Gravimetric Mass Balance (GMB) product for the Antarctic Ice Sheet (AIS), derived within the ESA Climate Change Initiative continuation project AIS_cci+. For the first time, the GMB product is based on satellite gravimetry data acquired by both GRACE and its successor GRACE-FO (Follow-On). This product comprises (a) time series of monthly mass changes for the entire ice sheet and for individual drainage basins, and (b) gridded mass changes covering the entire ice sheet, spanning almost 19 years between 2002 and 2019. Our results are based on the monthly solution series CSR RL06, which was chosen based on a quality assessment conducted for a wide range of available solutions.

Temporal changes in Antarctic ice mass are derived on basin scale as well as from the gridded product, providing insights on the temporally varying spatial distribution of mass changes. The quality of the GMB products is assessed based on the quantification of their noise level. Spatial and temporal variations of surface mass balance (SMB) are derived by means of the regional atmospheric climate model RACMO2.3p2. The modelled cumulative effects of SMB variations are utilized to partition the overall mass changes observed by GRACE and GRACE-FO. This allows us to also investigate variations of ice dynamical changes over time. The GMB products as well as up-to-date mass balance estimates for the AIS and its drainage basins, along with their corresponding contribution to global sea level change, are freely available through a data portal hosted by TU Dresden (data1.geo.tu-dresden.de/ais_gmb).

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Compilation and application of the northern Antarctic Peninsula region spectral library to characterize and validate satellite data and monitor change in ice-free areas

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Ice-free areas in the northern Antarctica Peninsula region are mainly located within coastal areas. They are hotspots of terrestrial biodiversity that are closely related to dominant glacial, periglacial, fluvial, and coastal processes and landforms. Visible-near infrared and shortwave infrared (400–2500 nm) spectral reflectance has been shown to be a useful method for characterizing and monitoring soil surface and land cover features and conditions. The objective of this work was to compile site-specific spectral libraries for ground truthing and validation of remotely sensed satellite information to characterize and monitor the highly dynamic surface covers within ice-free areas of the South Shetland Islands and along the Danco Coast of the Antarctic Peninsula. Field and laboratory spectra were obtained from selected test sites using field measurements and samples taken during several field campaigns. The spectral libraries were compiled into a georeferenced database containing additional information such as field observations and determinations as well as soil and sediment laboratory analysis. Results have shown that the spectral libraries provide necessary details to spectrally differentiate complex land surface covers and processes. Furthermore, this information was key to interpret and validate multispectral satellite data such as LANDSAT (5, 7 and 8) and SENTINEL2 that cover larger ice-free areas and where changes were detected over time through the extensive available time-series. A random forest machine learning classification was used to obtain changes in the spatial distribution of the different surface covers and to determine recent retreat of glacial ice-fronts that are liberating further terrestrial land surfaces.

22

Observing Evolving Subglacial Conditions with Muti-Temporal Radar Sounding

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Airborne radar sounding is the primary geophysical method for directly observing conditions beneath ice sheet and glaciers at the catchment to continent scale. From single flow-lines to regional surveys to ice-sheet wide gridded topographic datasets, radar sounding profiles provide information-rich constraints on the englacial and subglacial environment. This can include roughness, lithology, hydrology, thermal state, melt, fabric, and structure for both grounded and floating ice. However, the snap-shot view provided by one-time soundings fails to capture subsurface processes across the time-scales over which they evolve and control ice flow. Doing so requires advancing multi-temporal radar sounding instruments, platforms, and data analysis. For example, point-measurements by ground-based or stationary sounder can be used produce local time-series observations of englacial and subglacial conditions. However, low-cost, low-power active and/or passive radar-sounder networks can dramatically extend the reach and scope of such measurements. Further, repeat surveys by sled-drawn or airborne sounders can capture seasonal and interannual subsurface variations. However, digitization of archival radar film are extending the temporal baseline for such comparison by decades, making multi-decadal studies of subsurface changes possible. Finally, the development of autonomous rover, drone, and satellite sounding platforms and systems promise to enable pervasive, stable, and frequent monitoring of subglacial conditions. Here, we discuss the advances, challenges, and the path forward to observing subsurface conditions across the full range spatial and temporal scales at which they occur.

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Present-Day Antarctic Ice-Sheet Mass Balance Estimates

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Contemporary studies on mass balance estimates of ice-sheets during the late 20th and early 21st century, including the 2019 Intergovernmental Panel for Climate Assessment (IPCC) Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), and the 2012 reconciled ice-sheet mass balance estimate study, seem to still exhibit large discrepancies in the estimates of Antarctic ice-sheet mass balance. The IPCC SROCC study stated with very high confidence, that during 2006–2015, Antarctic ice-sheet lost mass at an average rate of 155 ± 19 Gt • yr^{-1}. However, the reconciled ice-sheet mass balance study reported the Antarctica mass loss rate of 71 Gt • yr^{-1}, 1992–2011, more than 50% differences. The plausible error sources include inadequate knowledge of firn compaction/density to compute ice mass from elevation changes, when satellite altimetry data are used, and coarse spatial resolution (>333 km), and inaccurate knowledge of subglacial topography uplift resulting from glacial isostatic adjustment (GIA), when satellite gravimetry (GRACE/GRACE-FO) data are used. We used different contemporary satellite gravimetry data products, including mascons, Level 2 data products, and employed different post-processing methods, including leakage, Earth oblateness, GIA and other corrections, as a means to assess the uncertainty of Antarctica gravimetry estimated mass balance. In this contribution, we combine multi-mission satellite altimetry (ERS, Envisat, CryoSat-2, etc), and satellite gravimetry (GRACE, Swarm, GRACE-FO) at interannual scales, with gravimetry data contribute to nominal density estimates to correct satellite altimetry data, to obtain an improved estimate of Antarctic ice-sheet mass balance, and assess feasibility of acceleration signal detections.

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Understanding multi-scale ionospheric structuring processes in the polar ionosphere using GNSS measurements alone

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The polar ionosphere is primarily driven by magnetospheric convection and neutral circulation and undergoes structuring over a wide range of temporal and spatial scale sizes. This structuring is due to the interplay of mechanical forces, electrodynamics, and ionization chemistry. The ionosphere and its structures affect the propagation of any radio signal from ground- or satellite-based sources, thereby posing an array of challenges for these systems. These effects can be broadly classified into deterministic and stochastic based on their impact and scale sizes. Ionosphere affects radio signal through refraction, diffraction, scattering, and absorption and these effects are scale dependent. During this talk, I will demonstrate how GNSS measurements alone can be used to understand the multi-scale structures in the polar region. I will also give an outline on how this can be used for the predictions of ionospheric conditions for planning and real-time observations for correction/mitigation of ionospheric effects detrimental to the performance and accuracy of communication links and navigation systems.

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Spatio-Temporal Variation in Ice Flow Velocity of Polar Record Glacier, East Antarctica during 2016-2019

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Polar Record Glacier, one of the outlet glacier of East Antarctica has calved a few decades back detaching 26 km x 16 km part of this glacier between 1973 and 1989. Remote sensing based investigation of ice flow dynamics of Polar Record glacier has been conducted in this work. The study was carried out to estimate the flow velocity using offset tracking method for the melt season (December – February) of 2016-2019. The offset tracking based approach, due to its advantage over loss of coherence and phase unwrapping, was utilized. The Sentinel-1 Synthetic Aperture Radar (SAR) images (due to its high quality and high revisit time for continuous monitoring of 6 days interval) were utilized in this study. Ice flow velocity near the glacier terminus indicated higher velocity during January and subsequently showed lower values in December during 2016-2019. During February, the velocity showed variations in the region of higher velocity compared to the previous month. The maximum and minimum velocity of the glacier was found to be ~860 m/a and 10.8 m/a for the period 2016-2017, ~871.2 m/a and 7.2 m/a for the period 2017-2018, ~831.6 m/a and 10.8 m/a for the period 2018-2019. Results indicated that the maximum velocity occurred in the terminus part of the glacier and minimum was detected on the ice sheet portion of the glacier. Mechanisms contributing to the velocity changes near the tongue are highlighted.
Keywords: Polar Record Glacier, Sentinel-1 SAR data, offset tracking, flow velocity

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Physical habitat characterisation in the Sør Rondane Mountains using satellite remote sensing

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Less than a quarter percent of the Antarctic continent consists of ice-free areas (Burton-Johnson et al., 2016). The environmental conditions in these areas are among the most extreme on earth, and life is dominated by bacteria, mosses and lichens, which show a high degree of endemism (Vyverman et al., 2010). Microbial soil crusts grow slowly and are sensitive to the terrain and climate conditions (Tytgat et al., 2016). A structuring factor may be the total received solar energy, which impacts the local variability of soil temperature and humidity. The present study evaluates satellite remote sensing for the mapping of physical habitat characteristics of ice-free regions in the Antarctic Sør Rondane Mountains, in order to aid identification of favourable habitats for microbial soil crust development in remote and inaccessible areas. In particular, the generation of Digital Surface Models (DSM) from high resolution stereoscopic imagery and derivation of Land Surface Temperature (LST) from the Thermal InfraRed Sensor (TIRS) on board Landsat 8 is examined. The DSM elevation data are compared against in situ recorded GPS positions and tracks, and the 8 m resolution Reference Elevation Map of Antarctica (REMA) released in Mid 2018 (Howat et al., 2019). DSM derived from satellite acquisitions made over multiple years are compared. Satellite derived LST is compared against temperature loggers installed in the 2018-2019 and 2019-2020 field seasons, and finally the multispectral data from the Operational Land Imager (OLI) on board Landsat 8 is used to classify ice-free pixels in broad classes.

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UKANET-GPS: a geodetic network to record crustal deformation in the Antarctic Peninsula and around the Weddell Sea embayment

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Present-day rates of vertical and horizontal motion observed by GPS can be used to constrain and validate models of Glacial Isostatic Adjustment in Antarctica, but are also affected by shorter-term elastic or viscoelastic loading deformation in response to changes in surface mass in recent decades. This shorter-term transient response can be used to constrain mantle rheological parameters in regions where the recent history of surface mass balance is well known, and hence the relationship between rheological and seismological parameters can be better calibrated for wider regional use. This is particularly useful in areas where the mantle viscosity is thought to be low (of order 10^{19} Pa s or less), which has recently been suggested for parts of West Antarctica.

We report here on the upgrade of GPS sites along the Antarctic Peninsula and around the Weddell Sea embayment to enable near-real-time return of data to the scientific community, allowing transient solid-Earth responses to be monitored continuously. The data will also enable tectonic deformation and atmospheric parameters to be derived with much lower latency than was previously imposed by the logistical difficulties of servicing these GPS instruments. Preliminary results documenting the evolving surface velocity field across West Antarctica will be presented.

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Monitoring Evolutions of Abrupt Weather Episodes in Antarctica Using Daily-Sampled Space Gravimetry Solutions and Acceleration Approach

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As the primary input to the Antarctica ice sheet, exact knowledge of snowfall is important for Antarctica mass balance quantification, and its contribution to present-day global sea-level rise. Within which, the extreme precipitation events have been estimated to contribute to more than 40% of annual precipitation for the majority of Antarctica. However, because of the extreme weather conditions, limited in-situ precipitation observation is available. Nominal monthly GRACE solutions have been widely used to study Antarctic long term mass balance. By nature, GRACE observation has a denser coverage at the polar region and it is possible to improve the gravity field temporal resolution for polar region. Here, we developed an acceleration approach with improved error mitigation schemes to process the GRACE/GRACE-FO KBR data and estimate sub-month temporal gravity field (11 days) with daily sampling over Antarctica, enabling detecting and quantifying the evolution of large snow-storm events, such as the 2006 episode on the Antarctic Peninsulas.

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SESSION 12

SURFICIAL PROCESSES-GEOMORPHOLOGY, CHEMICAL WEATHERING, EXPOSURE AGE DATING, AND PERMAFROST DYNAMICS

Berry Lyons
Mauro Guglielmin, Melisa Diaz

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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The role of microparticles of organic carbon in degradation of ice cover of polar regions of the Earths and in the process of soil-like bodies formation

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Rapid glaciers retreatment in polar and mountain regions of the Earth is resulted from not only direct effect of the climate changes, but, at the same time, with the global transfer of micropartciles and their accumulation on the surface of ice. An accumulation of these microparticles on the glaciers surface result in changing of albedo values and ice-sheets degradation. The cryoconites play a specific role in glaciers degradation, these formations are presented by specific orgainc soil-like bodies. They present self-deppening dark colored formations and aggregations in the surface part of the glacier. Incide the ice layer, they become aggregates and form space-developed web of organo-menral material, which finally result in intensification of deglaciation. In this context complex investigation of this process with use if numerous instrumental and molecular methods has been conducted. Data obtained with the use two-dimensional NMR spectrometry indicate that the stabilization rate of organic matter of cryoconite is higher than is soils of adjacent terrestrial ecosystems. Data on chemical composition of cryoconites are discussed as well new information about the component composition of polycyclic aromatic compounds. Microbial community of the cryoconites on the base of metagenomic analyzes is characterized as well.

This study has been supported by Russian Foundation for Basic Research, projects No: 19-54-18003 and 19-05-50107

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Ornitogenic soils of Livingstone and King-George Islands, Western Antarctica

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The present study is devoted to investigation of the role of the bird in soil formation and initiation of biogenic-abiogenic interactions in the terrestrial ecosystems of Livingston and King-George Islands. The ornitogenic soils of the investigated areas could be divided into three categories: 1 soils of the penguin rockeries with slightly decomposed guano (classic ornitogenic soils), 2 soils, formed under transported materials of plants, used by birds for nest building and remnants of food (skua rocks), soils under birds transported remnants of mollusks and fish (petrel rocks). Also, the postornitogenic successions are well pronounced in the terrestrial environments of the territory investigated. The first stage of this succession is presented by leaching of guano components and migration of leaching products in adjacent landscapes and colonization of postornitogenic plots by the algae – Prasiola crispa. The next stage is represents colonization of soils by vascular plants Deschampsia Antarctica and Colobanthus quitensis. This is very important in terms of soil formation cause results in formation of developed humus horizon with evident crumb structure and high humification rate of organic matter. According the soil morphology and spatial distribution, the territory investigated could be classified as maritime tundra with the dominance of Cryosols Ornitic Hyperskeletic. Data of 13-NMR spectrocscopy of organic matter of various ornitogenic soil showed the higher degree of stabilization rate of humic acids, formed under vascular plants, than in those, sampled under fresh guano.
This work has been supported by Russian Foundation for Basic reasearch, projects No 19-54-18003, 19-05-50107 and 18-04-00900

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Evolution of the Eastern Antarctic Ice Sheet in Queen Maud Land since the Late Miocene

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The spatial distribution of the dramatic surface lowering of East Antarctic Ice Sheet (EAIS) in the Queen Maud Land for the last million years is not yet fully explored. Today, Sør Rondane Mountains acts as a barrier to the EAIS. Around 1000 m difference in altitude of the ice surface to the south and north of the mountain chain shows this barrier and today's drainage pattern. In this study, we used suite of cosmogenic nuclides (10Be, 14C, 26Al and 36Cl) in 38 rock surface samples to decipher the timing, magnitude and frequency of the surface lowering history and change in drainage pattern of the EAIS in the western Sør Rondane Mountains. Our results show that the surface of the EAIS was at least 400 meters higher than today from the Late Miocene until the Pliocene Warming and that the major drainage was towards northeast over the mountain range. At the beginning of Pliocene, ice surface started to sublimate, and the south-north drainage was broken by prior to ca. 1.3 Ma. This caused the ice drainage to be channelized into either few main valleys or around the mountain range. Afterwards, the glaciation continued until around 130 ka, when a dramatic decrease in the ice surface elevation occurred in the ice lowlands to the north of the mountain chain. However, the ice plateau to the south seems not to be affected by the dramatic changes occurred on the northern side of the mountain range.

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Permafrost and active layer temperature regimes and their geographical controls (Barton Peninsula, King George Island, Antarctica)

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The South Shetlands are located off the northern tip of the Antarctic Peninsula close to the climatic limit of permafrost. The climate is cold oceanic with mean annual air temperatures of ci. -2°C at sea-level. Boreholes drilled in bedrock show permafrost temperatures of -1.8 ºC at mountain sites (270 m) and the absence of permafrost close to sea-level.
Until the Antarctic season of 2018-19, the deepest borehole in King George Island was at low elevation Bellingshausen station in Fildes Peninsula (8 m deep) with temperatures of -0.35 ºC. Data on permafrost temperatures, in boreholes deeper than 10 m was fully lacking in King George Island, and hence a new borehole integrated in the PERMANTAR network and in GTN-P was drilled in 2019 in Barton Peninsula. The King Sejong Station Borehole was drilled in massive andesite at 128 m asl, reaching a depth of 13.2 m. Temperature data is recorded hourly using a datalogger with 15 temperature sensors. 20 ibuttons were installed in different terrain settings to monitor the spatial variability of ground surface temperature.
We present the analysis of the ground temperature regimes for the period 2019-20 and provide a first insight on the permafrost conditions in Barton Peninsula, with -1,5°C at 13 m depth. Snow cover is examined using Sentinel-1 and ground temperature and freezing and thawing indexes are analyzed using a GIS in order to assess the geographical controlling factors. The first data on ground temperatures associated to the warm summer of 2019-20 is discussed.

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Million-Year-Old Ice Found Near Surface; Ong Valley, Transantarctic Mountains, Antarctica

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We have discovered a massive buried ice mass in Ong Valley, Transantarctic Mountains, Antarctica, from which we collected two 10-meter ice cores. This ice mass is buried under a thin layer (< 1 m) of sublimation till and cosmogenic-nuclide measurements from the overlying till have revealed a minimum exposure age of > 1.1 Ma, therefore making this one of the oldest ice bodies found on Earth.

To obtain additional constraints on the age, origin, and sublimation rate of the ice, we measured concentrations of the cosmic-ray produced nuclides ^{10}Be, ^{26}Al, and ^{21}Ne in englacial sediment in one core. These nuclides are produced by cosmic-ray interactions with minerals near the Earth's surface. As the production rate decreases rapidly with depth below the Earth's surface, nuclide concentrations can yield information about the age of the ice, and the rate at which the till is forming due to ice sublimation, and surface erosion rates. In addition to the cosmogenic nuclide measurement, we have analyzed deuterium and oxygen isotopes throughout the ice core.

Large downcore variations in both water isotopes and cosmogenic nuclide concentrations suggests that the last few meters of the ice core may belong to a separate, older ice body that has previously been exposed at the surface and most likely buried during a later glacial advancement into Ong Valley. Lateral moraines and till located further up valley suggest that this deeper ice mass may be > 2.6 Ma old.

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Deglaciation of large East Antarctic glacial basins that are grounded below sea level. A study of the Denman Glacial Basin

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Parts of the East Antarctic Ice Sheet (EAIS) such as the Aurora and Wilkes subglacial basin are grounded mostly below sea level. Here, the ice is susceptible to Marine Ice Sheet Instability that may rapidly destabilize the subaerial ice mass. Modern measurements of ice drainages in this region are accelerating and thinning at high rates, but we lack the geologic records of past ice sheet behaviour in this area needed to provide context for the modern rates of change, and calibrate numerical ice sheet models used to simulate future ice sheet response. In this study, we apply cosmogenic ^{10}Be exposure dating of glacial erratics, to investigate one of the major drainages of the Aurora Basin, the Denman Glacier to determine its past behaviour.

Preliminary data suggest the retreat and stabilisation of the Denman Glacier was completed relatively early (~11 ka BP), suggesting a rapid response to climate and sea level changes following the Last Glacial Maximum (LGM). This contrasts to previously studied regions that are grounded mostly above sea level including Dronning Maud Land, Enderby Land and Mac Robertson Land, where ice sheet retreat and thinning continued for at least another 2-7 ka, stabilising as late at 5 ka BP.

Here we present a more complete picture of the deglaciation timing of Denman Glacier since the LGM and assess the vulnerability of large glacial basins that are grounded largely below sea level to a warming climate.

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Geochemical and Sedimentological Characteristics of Modern Beach Sediments from Southern Part of Coastal Area at Hannah Point, Byers Peninsula, Livingston Island-South Shetland Islands, Antarctica.

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This study presents to research characteristics of modern beach sediments from Southern part of Hannah Point located in between coordinates 62°39'14" S and 60°36'39" W, Byers Peninsula at Livingston Island.

The purpose of this study is to investigate geodynamics of sediments with their provenance such as; glaciogenic, lithogenic , volcanogenic, cosmogenic, ornithogenic and also anthropogenic at Hannah Point cove.

In order to realization of this research with the integrative approach will be applied to study sedimentological and geochemical characteristics of sediments with their constituents such as; minerals, major and minor elements, carbonates and also organic carbon contents.

So, the fourteen samples from studied area where consist of loosely admixtures of large sized gravels, especially sand, silt and clay in variable proportions were collected at each sites located approximately 50 m apart from ice-free area to pioneer investigations during 2018 Antarctica austral summer. These samples were taken with a small hand shovel and kept to analyze at laboratory. Those are already analyzing at the laboratory.

As a result, the preliminary observations with varying gravel sizes on beach marks coastline which is seen that it is strongly affected by changing of tidal levels at southern part of Hannah point cove. This phenomenon tells us that the area is also hopefully under the effect of regionally geodynamics with changing of seasonal conditions in this place. Gravelly (boulder to granules) and sandy character of the beach area is also visible at steep and gentle slopes with exposing area at this side of Hannah Point.

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Chemical weathering and development of clays, sulfates, and chlorides at a transient Dry Valleys brine pond and relevance to Mars

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The cold and xeric conditions of Antarctica's McMurdo Dry Valleys (MDV) provide an opportunity for investigation of geochemical processes, including chemical weathering, in extreme environments. Furthermore, the cold, dry, ice-free conditions of the MDV present a compelling analogue for the cold, desert environment of Mars. The MDV has been the focus of numerous studies as one of the closest environmental and geological analogues to the martian surface. Central to this comparison is the search for habitable conditions, whereby scarcity of surface water in the MDV can nonetheless lead to occurrence of life. Decisive evidence of past or present habitability remains elusive on Mars, but occurrence of aqueous minerals (e.g., clays, sulfates, chlorides) suggests a complex history of water. We seek to better understand this aqueous history of Mars through study of the development of similar minerals in the MDV. We characterize sediments collected from an intermittent brine pond. These sediments somewhat resemble salt-rich outcrops on Mars, which potentially formed in similar brine systems. Through coordinated geochemistry, spectroscopy, and mineralogy we describe the suite of minerals that have developed in response to the activity of transient liquid water at this site. We observe that surface sediments are characterized by hydrated chlorides, beneath this a chemically active clay layer occurs, and at greater depths, sulfates occur. Development of clays, sulfates, and chlorides provides a direct analogue for formation of clays during activity of liquid water, and of sulfates and chlorides during evaporitic activity, at ancient salt ponds in cold environments on Mars.

1035

The microbiology of ephemeral meltwater systems of McMurdo Dry Valleys as analogues of Martian gullies

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The surface of the McMurdo Dry Valleys is mainly unconsolidated permafrost. Despite cold and dry conditions, gullies and streams occur during the summer as dark bands on north-facing slopes, from surface top-down melting of snow and ice. They host biological activity that can persist even after water flow has ceased in a cryptobiotic state. These systems may provide important insights into the potential configuration of Mars, in which ephemeral streams and rivers could have originated through processes related to the presence of liquid water more recently than 5 Ma, and could have hosted life forms remained trapped within the gullies. In this optic, soil fungal and bacterial diversity have been characterized via metabarcoding sequencing, in the areas surrounding Lake Fryxell, Lake Hoare and Lake Joyce. We found 11026 and 292 OTUs for bacteria and fungi, respectively, with richness ranging from 1683 to 2935 and from 7 and 122 OTUs, respectively. Main bacterial phyla within Lake Hoare and Lake Joyce communities were Bacteroidetes and Firmicutes, whereas, Lake Fryxell samples showed 28% Cyanobacteria and 3% Deinococcus-Thermus, nearly absent in the other two sites. For fungi we highlighted a dominance of saprotrophic and lichen-forming organisms and a high degree of diversification at phylum level in all samples. Edaphic parameters (soil texture, pH, moisture, C, N, cation exchange capacity and exchangeable cations Na^+, K^+, Mg^{2+} and Ca^{2+}) have been tested for correlations with richness and community composition, in order to reveal environmental factors relevant to the terrestrial limits and possible extraterrestrial establishment of life.

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Geoelectrical study of the permafrost and active layer near the Korean Antarctic Station, King George Island, Maritime Antarctica

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Under the framework of the Project Hydrotomo of the Portuguese Polar Program a geoelectrical study was started in January 2018 near the Korean Antarctic Station King Sejong to study the possible influence of permafrost and active layer dynamics in the evolution of mosses and lichens. The study area is located in the Barton Peninsula of King George Island of the South Shetland Islands archipelago. The study area has a rectangular shape of 40 m by 6 m and all the geoelectrical profiles were carried out along the largest side of the area; furthermore, to try to detect any permafrost and active layer thickness time variation, two times a week, during three weeks, three parallel electrical resistivity profiles, spaced by three meters each, were carried out. In each electrical resistivity tomography 40 active electrodes separated by one meter were used in a Wenner configuration. A Lippmann LG High Power equipment was used to measure the apparent electrical resistivities along each profile. The geoelectrical survey allowed detecting the top of the permafrost as well as water zones in the study area. Even preliminary, the obtained results appear to indicate that there is a relationship between high electrical resistivity zones with zones lacking mosses or lichens and vice-versa. Hopefully, the data obtained will allow constructing in the near future three dimension models of the subsurface electrical resistivity distribution.

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Geoelectric survey to study the ground state beneath facilities of the Peruvian Antarctic Station Machu Picchu

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A geoelectrical survey using electrical resistivity tomographies was carried out in January 2019 under the facilities of the Peruvian Antarctic Station Machu Picchu. The station is located in the Admiralty Bay of King George Island of the South Shetland Islands archipelago. The main objective of the survey was estimating the depth and the lateral extent of the frozen ground found beneath the main building of the Machu Picchu station during maintenance work performed in the antarctic summer of 2018.
Two rectangular shaped buildings of the Machu Picchu Antarctic Station were chosen to measure the ground electrical resistivity beneath them. In the biggest building the electrical profiles crossed 14 m beneath it along its smallest dimension; in the other (a refuge) the electrical profile crossed 7 m beneath the building, also along its smallest dimension. To carry out the geoelectrical profiles 40 active electrodes were used in a Wenner configuration; 1 m and 2 m distance between adjacent electrodes were used for different profiles.
Preliminary interpretation of the electrical resistivity data indicates that in both buildings there is a small layer of frozen ground which has also been detected by thermometers installed in 2018, as well as by eye inspection after digging a small hole to install new thermometers. However, beneath the frozen ground layer, coinciding with the area of both buildings, a low electrical resistivity layer, about 1 to 2 m thick, with electrical resistivity values as low as 20 Ω.m, was found.

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Geoelectric survey to study the aquifer that provides water the Peruvian Antarctic Station of Machu Picchu

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A geoelectrical survey using electrical resistivity tomographies was started in January 2018 near the Peruvian Antarctic Station of Machu Picchu, located in the Admiralty Bay of King George Island of the South Shetland Islands archipelago. The main objective of the survey was to attempt delineating the geoelectrical structure of the aquifer that provides water for domestic use to the station to estimate the aquifer's lateral and vertical extensions so that a better exploitation plan could be devised; furthermore, since the station is located a few meters from the coast, the work also aimed at identifying areas of possible saline intrusion. The study area (about 90,000 m2) presents glacial, alluvial-glacial, alluvial, alluvial-fluvial, and marine sediments (mostly sandy gravels with some silty gravel layers); in the area where the aquifer is believed to exist several electric resistivity tomographies with lengths that varied from 100 to 300 m long were carried out. Hydrogeologic data were obtained from piezometers located within the area where electrical resistivity tomographies were done; water samples from the piezometers have electrical resistivity values ranging from 25 to 50 Ω.m. Preliminary processing of the geoelectric data obtained along two almost perpendicular directions indicates that several tomographic profiles have crossed the aquifer which appears to be several meters deep; the bedrock is deeper than 60 m. The aquifer formation presents electrical resistivity values that range from about 100 to 400 Ω.m.

677

Concentrations and deposition rates of acid soluble metals in Taylor Valley stream deltas – the sediment dynamics in rapidly changing fluvial systems

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Recent research has documented local rapid landscape change in a number of locales in the McMurdo Dry Valleys where ground subsidence due to melting ground ice, fluvial downcutting, and sediment movement has been measured (Levy et al., 2018). In Taylor Valley, two of the most dynamic fluvial systems are Wales and Commonwealth Streams, where net erosion has been cleared demonstrated. In the summer of 2017, we collected a series of sediment samples from the delta regions of both these streams. The samples were leached with 10% HCl and analyzed for Fe, Ba, Cu, Pb, and Zn, and in the bulk sediment, 210Pb was measured in order to determine sedimentation rates. The acid-leachable metal concentrations were very low, especially compared to total concentrations measured in Commonwealth Stream sediments. Our results suggest that environmentally available metals in these systems have had little anthropogenic contributions. Our estimated sedimentation rates, between 0.15 and 0.7 cm yr-1, support previous work that has established these streams as highly dynamic and subject to rapid geomorphological changes over the past ~15-20 years.

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Relative terrestrial exposure ages inferred from meteoric-10Be and NO3 concentrations in soils from the Shackleton Glacier region, Antarctica

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During the Last Glacial Maximum (LGM, approximately 25 ka), the East Antarctic Ice Sheet (EAIS) was larger and thicker than today. Modeling studies and field mapping data have shown that the increase in glacier height was not uniform across the continent, and the outlet glaciers which flow through the Transantarctic Mountains experienced the largest increases in thickness. As a result, ice-free areas which are currently exposed may have been inundated during the LGM, though the timing of glacial retreat is still unknown. We collected depth profiles of soils every 5 cm (up to 30 cm) from seven ice-free areas along the Shackleton Glacier, a major outlet glacier of the EAIS, and measured meteoric-10Be and NO3 concentrations to calculate relative surface exposure ages. We used10Be inventories and published delivery rates to calculate maximum exposure ages, which ranged from 1.67 Myr at Roberts Massif near the Polar Plateau to 495 kyr at Thanksgiving Valley closer to the Ross Ice Shelf. Meteoric-10Be concentrations were measured for three depth profiles of the seven profiles and there is a strong, linear correlation between 10Be and NO3. NO3 concentrations were used to estimate meteoric-10Be inventories for the four other locations. Percent error between the estimated and calculated inventories ranged from ~1-41%. The NO3 derived 10Be inventories were then used to estimate exposure ages. These results show that NO3 concentrations can be used in conjunction with meteoric-10Be to help interpret EAIS dynamics over time.

1371

The role of wind and subglacial inflow in the hydrological connection between the two lobes of Lake Bonney, east Antarctica

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Lake Bonney in Taylor Valley, east Antarctica, has two distinct lobes separated by a relatively shallow sill in a narrow channel referred to as the Bonny Narrows. Robert Falcon Scott passed through the Bonney Narrows in 1903 on his first expedition in the area and measured the channel width as being “17 feet”. This has allowed us to calculate that the channel was about 1 m deep at the time. Since then lake level has risen over 18 m and the channel is now ~ 80 m wide at its narrowest point. Water chemistry above the sill is similar in the two lobes, but differs significantly below the sill as each lobe has had its own history. West Lake Bonney (WLB) has a hypersaline bottom water, sourced from the underside of Taylor Glacier (also the source of Blood Falls) which is held back from East Lake Bonney (ELB) by the sill. The WLB brine is displaced over the sill and sinks on the ELB side following a former river channel until if finds its neutral buoyancy in ELB, about 6 m below the sill depth. In this presentation, we will show evidence of the nature of this connection. A logging conductivity probe left in the channel for a year shows that the brine overflow events are sporadic and controlled by a combination of water entering from under Taylor Glacier, and strong westerly wind events. We will also discuss impacts of this mechanism for the evolution of ELB chemistry.

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Geochemistry of semi-arid soils on volcanic or sedimentary parent materials from James Ross Island, Antarctica

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In most parts of Antarctica, specifically in arid and semi-arid conditions, soils are the results of limited weathering and pedogenesis. The semi-arid soils of Antarctica remains little explored. There, the use of geochemical data is considered an important tool to interpret possible pedological processes through the changing molecular ratios of elements with depth. In this study, the geochemistry of soils developed on different parent materials under a typical semi-arid climate was investigated, based on the quantification of the elements by various methods. Based on the major and trace elements geochemistry, the soil types are clearly differentiated by their geochemical composition, and highly affected by their parent materials. Based on the major elements abundances, chemical weathering is very limited. Using geochemical parameters to identify lithologic discontinuities, five profiles showed this characteristic. The apparent high chemical index of alteration and mineralogical composition, with kaolinite in the clay fraction, soils developed on the marine sedimentary rocks showed a pre-weathered nature, related to the ancient inheritance of Cretaceous paleoclimates, during which warmer climate led to intense weathering under subtropical conditions. Therefore, pre-weathering has a role in the mineralogical composition of Antarctic soils on sedimentary rocks.

1078

Landforms, soil classification and soil-landscape relationships in Vega Island, Antarctic Peninsula

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The ice-free areas of Vega Island, located in the Weddell Sea – East Antarctic Peninsula, are environments of complex geomorphological dynamic. We mapped and described the landforms of Cape Lamb, and classified soils according to Soil Taxonomy. Twenty landforms were mapped at a scale of 1:50.000, involving glacial, proglacial, paraglacial and periglacial landforms. The main geomorphological processes were fluvial erosion, gelifluction, aeolian abrasion and rockfalls, responsible by large-scale mass movements. Most soils were classified as Gelisols, notably at the sedimentary lowlands, whereas Entisols were more common in the volcanic highlands. The proglacial domain is represented by recent ice-cored moraines (30%). The soil classes in these landforms are Glacic Psammorthel and Glacic Haploturbel. The periglacial domain (10%) encompasses former, higher and stable surfaces, highlighting the cryoplanation platforms with patterned ground, felsenmeers and “Mesas” (former nunataks). The soil classes are Typic Gelorthent, Lithic Cryorthent and Typic Haploturbel. The paraglacial domain was the more expressive (60%), involving landforms like scree slopes, raised marine terraces, plains, beaches, talus-slopes and boulder fields. The soil classes in scree slopes are Typic Haploturbel and Typic Gelorthent. Typic Gelifluvent and Typic Gelaquent are the soil classes in plains, while Typic Psammorthel are present in marine terraces. The major formation factors of Vega Island landscape are: the geologic control, the glacial dynamic, the summer snow melting, the freeze-thaw cycles and the semiarid climate. The paraglacialism represents a young and transitional landscape recently recovered from last glaciation. Landforms influences directly the soil distribution, determining a strong soil-landscape relationship.

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Use of LIDAR data in the identification of mass movement processes of periglacial landforms on Keller Peninsula, King George Island, Antarctica

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The objective of this study was to identify the main geomorphic processes in the landscape of the Keller Peninsula using a terrestrial laser scanner (TLS) technology. For the reference database, it was used a cloud of points obtained in 2015 and a field campaign that was carried out in 2018 to obtain the comparison set. We chose to use the direct comparison technique in the cloud of points, through the algorithm m3c2, realized in the software CloudCompare v.2.10. A cloud of points was obtained with the information of the vertical distance between points, with an average threshold of 0.20 m for significant change detection. The results were related to the present geomorphological features and morphometric variables of the relief. Site one, which comprises part of the glacial circuses present in the area, presented processes predominantly related to crionival and slope systems. The site two comprised part of the Flagstaff Hill, being verified processes involved by gravitational forces and slope processes, with slope being the predominant factor for the changes in talus ramps. The third site presented processes is occurring high altitude, such as falls of cliffs on escarpments, besides crionival processes occurring in ramps and niches. The fourth site was the one which presented the lowest rate of altimetric change, with changes occurring in saturated terrains, positioned in high elevations and moderate slope. The use of Lidar data and high-resolution aerial images proved to be adequate in the identification of geomorphic processes in large areas.

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Landforms, soil classification and soil-landscape relationships in Vega Island, Antarctic Peninsula

Rafael Siqueira[1], Márcio Francelino[1], Carlos Schaefer[1], Elpídio Fernandes Filho[1]
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The ice-free areas of Vega Island, located in the Weddell Sea – East Antarctic Peninsula, are environments of geomorphological complex dynamic. We mapped and described the landforms of Cape Lamb-Vega Island, and we classified its soils according to Soil Taxonomy. Twenty landforms were mapped at a scale of 1:50.000, involving glacial, proglacial, paraglacial, and periglacial landforms. The main geomorphological processes were fluvial erosion, gelifluction, aeolian abrasion, and rockfalls, responsible by large-scale mass movements. Most soils were classified as Gelisols, notably at the sedimentary lowlands, whereas Entisols were more common in the volcanic highlands. The proglacial domain is represented by recent ice-cored moraines (30%). The soil classes in these landforms are Glacic Psammorthel and Glacic Haploturbel. The periglacial domain (10%) encompasses former, higher and stable surfaces, highlighting the cryoplanation platforms with patterned ground, felsenmeers, and “Mesas” (former nunataks). The soil classes are Typic Gelorthent, Lithic Cryorthent, and Typic Haploturbel. The paraglacial domain was the more expressive (60%), involving landforms like scree slopes, marine terraces, plains, talus-slopes, and beaches. The soil classes in scree slopes are Typic Haploturbel and Typic Gelorthent. Typic Gelifluvent and Typic Gelaquent are the soils classes in plains, while Typic Psammorthel are present in marine terraces. The main formation factors of Vega Island landscape are the glacial dynamic, semiarid climate, geologic control, ice-cemented permafrost, and concentration of moisture in the summer. The paraglacialism represents a young and transitional landscape recovering from the glaciation. Landforms influence the soil distribution directly, determining a strong soil-landscape relationship.

1634

Use of LIDAR data in the study of solifluction processes in periglacial landforms on Maritime Antartica

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We identified typical periglacial processes in the landscape of the Keller Peninsula using a terrestrial laser scanner (TLS) technology. For the reference database, we used a cloud of points obtained in 2015 and a field campaign that was carried out in 2018 to obtain the comparison set. We chose to use the direct comparison technique in the cloud of points, through the algorithm m3c2, carried out by the software CloudCompare v.2.10. A cloud of points was obtained with the information of the vertical distance between points, with an average threshold of 0.20 m for significant chance detection. The results were related to the observed geomorphological features and measured morphometric variables. Site one, which comprises part of glacial circus showed predominantly crionival and slope process. Site two comprised part of the Rocky outcrop of Flagstaff Hill, where gravitational forces and slope process are predominant factor for the changes of talus down slope. The third site at high altitude, showed rock falls, escarpment retreat and crionival process in ramps and niches. The fourth site was the most stable with the rate of surface changes, mainly in hydromorphic areas at high elevations and moderate slope. The use of Lidar data and high-resolution aerial images proved to be adequate in the identification of changing geomorphic process in periglacial areas of Antarctica.

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UAV image applied in the dynamics of the landforms on Keller Peninsula, King George Island, Antarctica

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This work had the general objective of comparing old aerophotographic bases with current images of high spatial resolution generated by Unmanned Aerial Vehicle (UAV), being certified its accuracy according to Brazilian cartography norms. For taking aerial images, used a small-format digital photographic set, embedded in UAV. Data collections were performed in the summers of the years 2018 and 2019, and two different databases were generated. Two sets of aerial images from the years 1956 and 2003 were reprocessed to carry out the temporal analysis of environmental changes. For this, techniques based on the Structure of Movement (SfM) were used. The results obtained were two orthophotomosaics with Ground Sample Distance (GSD) of 0.05 m (2018) and 0.04 m (2019), in addition to two digital terrain models (DTMs), with spatial resolutions of 0.30 m (2018) and 0.38 m (2019). Subsequently, the positional quality analysis was performed on the data obtained in 2019. The products were certified from one of a set of 36 independent points, evaluating the altimetric and planimetric accuracy. The generated products presented planimetric root mean square error (RMSE) of 0.1149 m and altimetric RMSE of 0.2488 m. As for the Cartographic Accuracy Standard for Digital Cartographic Products, the orthophotomosaic was classified as class A and the MDT class B; both tested on the scale of 1: 1000. The data collection and processing technique allowed the analysis of natural and anthropic aspects of the studied area, with promising applications in the assessment of the environmental dynamics of Antarctic ice-free areas.

1375

Temperature and Moisture Dynamics of the Active Layer in Wet and Dry Soils and Sediments of the McMurdo Dry Valleys, Antarctica

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In the McMurdo Dry Valleys, extensive open ground provides opportunity for atmospheric energy exchanges to influence active layer and shallow permafrost states and dynamics. We have monitored active layer moisture, temperature, and in a few cases salinity in locations adjacent to streams, lakes and water tracks, and at locations distal from water bodies for several years. These data reveal the expected annual cycle of freeze in the winter and thaw in the summer, though the shoulder seasons and presence of water clearly provide important controls on the extent of thaw and solute and moisture mobility. We also observe that summer snow accumulation has a significant impact on active layer processes by reducing the connection to soil surface energy fluxes. The implications of changes in water content of the active layer may play a role in affecting habitat for soil microbial and invertebrate communities.

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Blue ice moraines as natural archives

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Our previous work has shown that some blue ice moraines (BIMs) are invaluable quasicontinuous records of Antarctica's glacial history and subglacial processes. To expand this work, we analyzed high-resolution satellite imagery for ~100 moraines to investigate geomorphological patterns on BIMs, which can preserve temporal records of surface conditions. Many BIMs around Antarctica have zones of hummocky topography 10's - 100's m wide at their margin. This differential ice surface lowering is interpreted as a function of locally high ablation rates from (brief) seasonal melt where till cover is thin. This hummocky pattern is inferred to record relatively warm post-LGM conditions. The few BIMs that lack this hummocky topography are located at the highest elevations and/or most southerly locations. Further into the moraine, away from this contact, the pattern typically transitions to ridge/trough or flat topography. The shift indicates a lack of summer melt and/or lower sublimation rates such that the ridge/trough topography more clearly reflect emerging debris bands. Where surface exposure ages are available, this geomorphic change is consistent with the glacial-interglacial transition. In a few instances, hummocky topography appears in older sections of the moraine, reflecting past warmth sufficient to cause differential moraine surface lowering. Lastly, regions of convoluted surface morphology represent dynamic variations in ice input through time. Existing GPR data show consistent internal stratigraphy across BIMs indicating the processes of debris delivery have not changed substantially over time, but changes in debris concentration may be related to geomorphological variations.

1062

Landforms, geomorphic processes, and soils in a typical periglacial environment of Snow Island, Maritime Antarctica

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Despite the progresses in the last decade on periglacial geomorphology and permafrost research in Antarctica, many gaps remain. The present study aimed to identify and describe the main landforms of President Head Peninsula (PHP), Snow Island and investigate the soil–landscape relationships in a typical periglacial environment of Maritime Antarctica. The geomorphological analysis was based on the identification and mapping of landforms and their physiognomic aspects according to the adopted scale: 1:15,000. Landforms were previously identified in satellite images (Sentinel-2), later identified and georeferenced using portable GPS. The map was produced using the ArcGIS 10.1. The map legend includes eighteen (18) landforms classes identified. From the soil survey, we selected surface samples of ten (10) pedons to represent all different landforms. Soil morphological, physical, chemical and mineralogical properties were analyzed. We present the first systematic characterization and geomorphological map of landscapes from PHP. The area was divided into 2 large sectors: (1) sedimentary with paraglacial processes; and (2) igneous with periglacial processes. The paraglacial domain is more dynamic and presents immature and poorly developed soils. The existence of vegetated marine terraces unique to this part suggests the local greater stability and greater nutrients availability. Landforms associated with gelifluction, patterned ground and permafrost were only observed on the upper plateaus. The monitoring of landforms can aid in the understanding of climate changes. The knowledge on soil types and the soil-landscape relationship broaden the understanding of geomorphological aspects and main processes involved in landscape evolution.

1348

Surface colour and reflectance study to detect weathering rates in a raised beaches system in the South Shetland Islands, Antarctica

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Colour change is often a visible expression of chemical weathering and several chemical weathering processes, such as Fe-rich mineral oxidation, lixiviation and other alteroplasmation processes. Raised beach deposits are a common feature in the South Shetland Islands. These deposits, formed mainly by glacioisostatic evolution, consist of accumulations of rounded centimetre to decimetre size pebbles with no or little soil formation. The lack of soil makes these deposits to stay unmoved for a long time undergoing chemical processes. Surface colour of the pebbles changes as chemical weathering progresses, so a colour gradation, which is proportional to raised beach deposits height (and hence chemical weathering) can be established. This work presents spectral reflectance and surface colour data obtained from measurements carried out with a spectroradiometer (spectral range 350-2500 nm) and a portable spectrophotometer on individual pebbles from raised beaches located at different heights on Livingston Island,. Results show that alterations on the outer rock surfaces induced variations of the spectrum brightness, presence and intensity of characteristic absorption features. Spectral changes in the wavelength range 350-1000 nm were identified and related to the alteration of iron oxide by atmospheric processes or by secondary alteration of iron-rich minerals. Furthermore, spectral features at 2200 nm were related to Al-OH bands. Changes were also expressed in reddening and yellowing as measured with the spectrophotometer. These data are interpreted in terms of the relative age and time of exposure of different beach deposits in the studied system.

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What are the products of chemical weathering of aluminosilicate minerals in the streams of the McMurdo Dry Valleys?

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Research since the early 2000s by a number of McMurdo Dry Valleys (MCM) LTER scientists has clearly demonstrated that chemical weathering of aluminosilicate minerals takes place at high rates when liquid water is present in stream channels of Taylor and Wright Valleys. These processes are thought to primarily occur in the hyporheic zones of these channels where waters of differing residence time react with fresh mineral surfaces. Although there has been speculation that freeze/thaw action may also play a role in weathering processes, little work has been done to establish its importance.

We present three lines of evidence suggesting that the freeze/thaw process in the stream channels may exert a control on the high aluminosilicate weathering rates observed. We have run a series of laboratory experiments simulating freeze-thaw, as well as a frozen control, on crushed igneous rocks from the MCM. The freeze/thaw samples have much less H_4SiO_4 than the control over time, suggesting removal of dissolved Si through freezing. This loss has previously been reported by other authors. Additionally, PHREEQC calculations of major streams in the valleys shows continual undersaturation with respect to amorphous SiO_2 as well as primary minerals found in the stream sediments. Finally, SEM images and EDX spot analyses of reacted surfaces suggest the presence of precipitated amorphous phases coating some of the stream sediments. All of these data imply that freeze/thaw cycles in these streams during the austral summer remove previously solubilized H_4SiO_4, thus potentially increasing the rate of aluminosilicate mineral weathering in these systems.

1602

The Development of Blockfields in Western Dronning Maud Land: A New Model

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Blockfields are ubiquitous in Western Dronning Maud Land where the lithology is doleritic. We suggest a model for the development of autochtonous blockfields. The landforms originate after pre-preparation of the rocky material through extensive and prolonged weathering and dilitation after deglaciation. Intact bedrock is heaved into a disordered matrix that has no directional fabric by wedging that results from expansion when water from snow and ice melts penetrates joints and cracks freezes. Where a nunatak does not have either the pre-prepared matrix or sufficient moisture to cause ice-wedging, the surface is left intact and only the original joints and cracks. Our model helps to explain the existence of disjointed and chaotic rocky surfaces in the Ahlmannryggen. The development of the blockfields is a precursor to paedogenesis and the development of other permafrost and active layer landforms that provide a habitat for biological colonisation.

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Substrate preferences by iron(III)-reducing bacterial communities on iron oxide minerals after glacier retreated in polar and subpolar zones

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As glaciers retreats a new development of soils start, while the glacier front formerly covered with ice, undergo a succession of organisms. In this area there is a gradient of iron from ferrihydrite (FH) to a more crystalline forms like goethite (GT), hematite (HT) and magnetite (MT). Under anaerobic conditions, Fe-oxides can be easily reduced to soluble Fe(II) from iron reducing bacteria (IRB). There is growing evidence that the more crystalline Fe may support IRB in lower temperatures as terminal electron acceptors. We postulate that microbial reduction of poorly crystalline Fe can decompose more polymerized carbon (C) with lower turnover than more crystalline Fe with labile C. FH has more reducing capacity than MT, which allows microorganism to decompose fast simple substrates (e.g. acetate). A microcosm (liquid media) was prepared whit IRB extracted from Antarctic soil (glacial front) and incubated (5 ºC) with sterilized Fe-oxides combined with glucose, lactate and acetate. In addition, the catalysis of 19 L-amino acids (AA) were tested for enzymatic production. The results showed that the release of CO2 was maximal (235 mg kg-1 soil) for acetate-MT followed by GT = HT and glucose-FH. Acetate-MT solubilized a significant amount of Fe(III), since Fe(II) increased in 362%, while glucose-FH was the lowest. A positive and highly significant correlation (R2= 0.93) was obtained between AA catalysis and the enzymatic activity with acetate-MT. This activity increased linearly with the crystallinity of Fe-oxides. Therefore, the maximal Fe reduction should be in Antarctic soils with labile C and crystalline Fe-oxides.

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Active Layer Thickness at Seymor Island

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Climate change attention has grown in the 21st century; in 2020 record temperatures were reported at Antarctica catching the attention of the news worldwide. The permafrost is acknowledged as a crucial element for understanding future tendencies. Understanding of Antarctic permafrost is poor, especially at the Weddell Sea zone. Soil temperature records over transitional climatic zones are fundamental for understanding climate change at Antarctica. A monitoring site was installed at the northern sector of Seymour Island in the summer of 2011 (103 m a.s.l., -56,663917W / -64,25545S). It consists of 5 thermistors, an air temperature probe, (100 cm over the soil surface), recording data hourly from March 2011 until Feburary 2016. The active lawyer thickness was calculated as the 0 ˚C depth by extrapolating the thermal gradient. The variability of the active layer thickness shows great contrasts between years, the temperature at 5 cm reaches a maximum daily average (8.3˚C, 2011) in mid December, a minimum (-30.3, 2011) in late July. At 100 cm maximum temperature (0.7 ˚C, 2016) occurs in early February and the minimum (-19.4 ˚C, 2011) was recorded around late July. The active layer thickness increases from 2011 to 2012 (102,2 cm to 113,1 cm), decreasing in the next two years (73,79 cm and 89,08 cm) and assumed a increasing tendency in 2015 reaching its maximum thickness of 123,4 cm in 2016. The active layer thermal regime in the studied period was characteristic of periglacial semi-desert environments, with extreme variation in surface and negative temperatures even during summer.

1040

Geology and geomorphology of Seymour Island (Marambio) (NW Weddell Sea). new maps and accompaigned book

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Recently, new Antarctic maps with scientific memoir: 'Geology and Geomorphology of Seymour Island (Marambio)' was released. Maps and book have been edited by Geological Survey of Spain (IGME) and Argentine Antarctic Institute (IAA), in an international collaborative effort support from both institutions and Spanish Polar Programme, within the new "Antarctic Geoscience Cartographic Series" of the IGME. This work, together with the "Geology and Geomorphology of Hope Bay", constitutes the two first products of the mentioned series.
The Geological and Geomorphological maps (scale 1:20,000) of Seymour Island (Marambio) (NW Weddell Sea) cover its entire surface. The absence of permanent ice permits to observe the unique outcropping series for the reconstruction of the Cretaceous-Paleogene geological history in southern latitudes, included the mapped outcrop of most continuous extension of the K-Pg boundary and the southernmost one of the planet.
The fossil record is singularly rich and abundant in groups like: ammonites, vertebrates, micropaleontology, paleobotanic and mollusk accumulations (coquinas), among others. In addition, the upper strata of Seymour Island (Marambio) next to the Eocene-Oligocene boundary in age, record the opening of the Drake Passage, which contributed to the thermal isolation of Antarctica and global cooling and the beginning of the development of the present-day Antarctic ice sheet.
These maps can help to protect this paleontological heritage.

Reference: Montes, M. et al (2019). Geología y Geomorfología de isla Marambio (Seymour). (Montes, M.; Nozal F. y Santillana, S., eds.). Serie Cartográfica Geocientífica Antártica; 1:20.000, 1ª edición. Acompañado de mapas. Madrid-IGME; Buenos Aires-IAA, 300p.

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Exposure age, provenance, and weathering of glacial tills Ong Valley, Antarctica

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Ong Valley, Antarctica contains a sequence of three tills, two of which are underlain by relict glacial ice. We use the concentration of cosmogenic Beryllium-10 and Neon-21 in quartz from bedrock and glacial boulders to determine the exposure age of the glacial tills. We collected bedrock samples above the glacial limit, and calculated long-term rates of erosion using the concentration of cosmogenic Ne-21 in quartz from the bedrock, yielding rates of 0.14 – 0.41 m/Ma. Be-10 and Ne-21 exposure ages of the lateral moraine closest to the older ice body are at minimum 1.1 Ma, indicating the ice is at least that old. A second lateral moraine in between the two ice bodies yields an exposure age of at least 475 ka, providing an apparent maximum age for the younger ice body. We extracted detrital zircon minerals from the glacial tills, the buried ice, and from the modern ice front to use as a proxy for the provenance of the glacial tills in Ong Valley. The distribution of the Uranium-Lead ages of the zircon minerals from each till are statistically the same, indicating that the provenance of each till is the same. We interpret this to mean that the Argosy Glacier that deposited the tills in Ong Valley had the same flow patterns to deposit each till. Additional data on the chemical index of alteration of the bedrock and tills, and aerosol salt accumulation in the tills indicate a weathering-limited environment in Ong Valley.

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Biogeochemical cycling of dissolved trace metals in freshwater lakes of Larsemann Hills, East Antarctica

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Coastal lakes in Antarctica during austral summers receive enormous solutes such as major ions and trace elements, of which some of them are used as nutrients that support biological productivity in these lakes. Freshwater lakes in Antarctica are hotspots of biological activities and inorganic precipitation, characterised by high rates of nutrient attenuation and salt-formation. We have investigated trace metals along with biological parameters (dissolved organic carbon and chl.a) to understand their role in nutrient dynamics and biogeochemistry of freshwater lakes of Larsemann Hills, East Antarctica. The concentrations of dissolved trace metals are in sub-nanomolar range, an order of magnitude lower than global rivers which limit the primary productivity such as chl. a concentration (0.24 ± 0.19 mg/l) and supports the oligotrophic characteristics of the lake waters. In the present study, dissolved Mo is identified as limiting micro-nutrient among the trace elements (e.g. Cu, V, Mn, Ba, Cd, Cr, Co, U) studied in these lakes. Whereas an active role of dissolved Cu in organic decomposition was observed in the lakes. Inorganic and/or biological mediated precipitation of Ba and Mn are widespread on the lake sediments. Evaluation of Ba excess estimated for lake sediments varies from 25-50% also supports these findings and suggests the inorganic attenuation in the lakes. Overall, this study explains the individual responses and behaviour of trace metals in the Antarctic lakes. This work is of great importance to better understand the biogeochemical cycling of trace element and their critical role in the nutrient-deficient lakes in the Antarctic environment.

Geomorphological processes in advancing moraines: A comparison between two proglacial areas in Antarctica

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This work assesses the morphological consequences of recent (post-'Little Ice Age'-LIA) paraglacial reworking of advance moraines in two areas: Hope Bay (HB) in the Antarctic Peninsula and Fildes Peninsula (FP) in King George Island, South Shetlands. We have analyzed hydrological processes, topography, snow melting, slope exposure, slope, particle-size, vegetation, and exposure time of the advancing moraines. In both areas, there is a later-frontal hummocky morainic complex, formed by glaciers that advanced during the LIA. Gully systems are observed in the steepest portions of FP and HB, forming debris cones, which already have a vegetation in the former one. The FP advance moraines are 100 m from the Collins glacier terminus, in the ice-marginal environment, are 8 to 10 m high and about 1.5 km long. The sedimentary material is varied, from large blocks to silt and clay. Low slope moraines near the Maxwell Bay (FP) are covered by vegetation fields of up to 0.03 km², denoting a reduction in geomorphic activity in this area. However, active slumping can also be observed in the FP moraines, but in the ice-distal face, associated with steep slopes. The HB moraines are about 300 m distant from the Buenos Aires glacier and are 500 m long. Boulders predominate, where lichen fixation occurs. Some moraines are surfaced deformed, due to melting of internal ice. The different evolutionary stages of the proglacial environment are explained by the location of the moraines, vegetation fixation, morphometry and granulometry of the sediments.

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The Geomorphons Method applied to the identification of glacial relief forms in the ice-free areas of King George Island

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This study aims to contribute to the understanding of the relief of ice-free environments in Antarctica, presenting a method of automatic classification of paraglacial and glacial landforms, called Revised Geomorphon Digital Classification (RGDC). This method was applied using the textural similarity of the References Elevations Models of Antarctica (REMA) 8 for ice-free areas of Potter Peninsula (PP), Fildes Peninsula (FP) and foreland of Fourcade Glacier (FG) and Ecology Glacier (EG) in King George Island, South Shetlands, Antarctica. The relief elements identified by the methodology are related to the erosive and depositional glacial forms at macro and meso scale (advance moraines, circus and U valleys, horns and aretes). Elevated beaches at FP and PP areas were classified, there it is possible to observe a sequence of features that correspond to different moments of land rise after deglaciation. The method was unable to identify features such as eskers and moraines of recession in PP, FG and EG, which are forms of mesoscale, and discontinuous moraines that weren't identified in the crest class. Older forms in deglaciated areas, as in FP, have been reworked difficulting the identification by the Geomorphon method, due to the smoothing of the forms and less roughness. Data from previous mappings and observations from fieldwork (2015, 2016 and 2019) showed that RGDC and REMA 8 data can be applied to geomorphological mapping aimed at paleoglaciological studies.

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Cryosols in sorted patterned ground at Nelson Island, Maritime Antarctica: properties, mineralogy and micromorphology

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In polar regions, patterned ground (PG) is considered one of the most distinctive surface feature with permafrost, as well as one of the main periglacial features of Maritime Antarctica. Despite all previous works on physical properties and formation mechanisms for PG reported in the Antarctic environment, little attention was given to their chemical and micromorphological attributes. In this study, we evaluated the development degree of PG soils in ice-free areas of Harmony Point, Nelson Island, Maritime Antarctic. Three pedons were selected for physical, chemical, mineralogical, micromorphological and micromorphometric analyses. The most developed PG Turbic Cryosol shows clay loam texture in the central mudboil, and skeletal composition at the external ring. Smectite and kaolinite are the main clay minerals. Micromorphological analysis in the external ring indicates strong frost action manifested by a vesicular microstructure. The clayey mudboils present a block microstructure, separated by thin and elongated planar pores due to frost shrinking processes. Little chemical weathering was inferred by preservation partially saussuritized plagioclases in the coarse material. The micromorphometric analysis showed circular rotation grains orbiculic, controlled by the cryoturbation process. Pedofeatures as silt and silt-clay cappings occur on rock fragments, jointly pores with complete and discontinuous in-filling with organo-mineral material. Permafrost was ubiquitous and cryoturbation is a key soil-forming process in these areas. With these characteristics in mind, one can consider that Harmony Point processes one of the most extensive and well-formed of sorted patterned grounds with cryoturbated mudboils in South Shetland Island, with varying degrees of development and plant colonization.

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Sampling methodology for characterization of geochemical and microbiological impact of acid rock drainage in seawaters and sediments from Cardozo Cove, Antarctica.

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We present the methodology and first preliminary results from the Peruvian Antarctic campaign ANTAR XXVII. The aim of this investigation is to study the effect of acid rock drainage (ARD) in the water column and in sediments. The ARD was reported for the first time previously from the Cardozo Cove in King Georg Island, Southern Shetland Islands, Antarctica by Dold et al. (2013). The ARD formed through oxidation of sulfide (~10% pyrite) containing rock units, occurring in the coastal part of the bay, liberating important amounts of Fe and associated elements to the sea. In order to track the biogeochemical processes along the flow path from the source to the open sea, three sampling locations were selected along the Cardozo Cove. Sampling was done in the water column by using a rosette with 24 Niskin bottles, including a CTD for physical parameters (T, Conductivity, dissolved O_2). Sediment cores were obtained by a piston corer (obtained cores ranged from 1 - 2.5 m). Pore water was extracted by Rhizon samplers and conserved for cation and anions. Samples for microbiological characterization and petrographical/geochemical analyses were taken from the sediment profiles at the same depth than the pore water samples.

Dold, B., Gonzalez-Toril, E., Aguilera, A., Lopez-Pamo, E., Cisternas, M.-E., Amils, R. (2013). Acid rock drainage and rock weathering in Antarctica – important sources for iron cycling in the Southern Ocean. Environmental Sciences & Technology. 47(12). 6129–6136.

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Digital soil mapping of functional soil properties of the McMurdo Dry Valleys

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While microbiologists face a range of questions concerning the biodiversity of terrestrial systems in ice-free regions, a major hurdle is the sparse coverage of soil information. The spatial distribution of microbiological communities has been shown to be strongly influenced by soil attributes (eg water content, salinity, organic carbon, pH). But while pedological maps have been published for various ice-free regions across the continent, the spatial distribution of those soil attributes themselves is largely unknown.

The use of digital soil mapping (DSM) has been tested to address this lack of soil attributes information: local soil observations, derived from a range of legacy studies, but also from data of opportunity collected every season, can be combined with a range of spatial layers reflecting different factors of soil formation using a machine learning model, in order to predict the spatial distribution of soil attributes measured at those locations.

Here, we are collating and harmonising data from different studies to investigate the spatial distribution of pH, one of the critical soil properties for understanding life distribution in Antarctic soils. Since other parameters of interest are also measured, this opens an opportunity to extend this soil information system to other important soil properties for the region (eg salinity, carbon).

The application of those digital soil mapping techniques can (i) be a tool to understand and predict where microbial habitats occur, and (ii) has the potential to generate base layers for researchers outside the soil science community (in particular the fields of microbiology and climate change).

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An early deglaciation at sub-Antarctic Marion Island from cosmogenic 36Cl exposure dating: implications for landscape development

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Glacial oscillations of the Quaternary provide valuable insights into past and present climate linkages. For the Southern Ocean, the sub-Antarctic Islands provide a valuable terrestrial record of glacial chronologies, since they are unique, not only in size and topography, but also in oceanic situation when compared to other continental landmasses (e.g. Antarctica or Patagonia). On Marion Island, southern Indian Ocean, rates of periglacial processes, soil and peat formation, and ecological succession were largely based on the premise that the island was under full glacial conditions during the global Last Glacial Maximum (LGM) and had undergone rapid deglaciation prior to the Holocene. Here we present a new glacial chronology for Marion Island from cosmogenic 36Cl exposure dating of glacial erosional and depositional features. Exposure ages of coastal moraine boulders show that the onset deglaciation was prior to ~35 ka ago and by the peak of the global LGM (~20 ka ago) bedrock surfaces at 850 m a.s.l. were already exposed. No evidence of Holocene re-advances, e.g. during the Antarctic cooling period, have yet been found, but these would have been restricted to the island's interior above 900 m a.s.l. We suggest that, during the gLGM, a combination of Antarctic sea-ice expansion, the northward migration of the southern westerly winds and oceanic fronts brought drier conditions to Marion Island, causing glacial retreat instead of advance. Our findings require a re-evaluation of the location and timing of the ice-free areas which acted as biological refugia and primers for periglacial landscape development.

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Active layer thermal regime at three different plant communities at Maritime Antarctica

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Soil temperature and moisture regimes are key drivers of abiotic and biotic processes in the Antarctic region. These environmental variables are considered essential in any consistent monitoring of global climate changes affecting the permafrost and active layer. In this work, we analyzed changes in the thermal and hygrometric regimes at fine-scale in three Cryosols of Elephant Island, Maritime Antarctica, under different vegetations. We selected three sampling pedoenvironments, with contrasting soil properties and plant communities. Ten plots (20 × 20 cm) were established in each pedoenvironment. Vegetation coverage, soil properties, air temperature, and soil temperature and moisture at three depths (10, 20, 30 cm) were measured. Three distinct communities were identified in different soil types: moss carpet community (MCC) with Turbic Leptic Reductaquic Cryosol; fruticose lichen community (FLC) in a Turbic Leptic Skeletic Cryosol, and moss turf community (MTC) in a Turbic Leptic Eutric Skeletic Cryosol. Our results showed that MCC had higher vegetation cover, which promoted higher temperatures at the active layer. Plant coverage has allowed to conserve higher values of soil temperature with less variability, as well as to reduce evaporation, despite high soil moisture contents observed in MCC. We infer that an increase in soil temperature promotes higher organic matter decomposition that results in higher soil fertility by cycling in MCC. The plant coverage has an important role in mediating soil temperatures and moisture variation at a fine spatial scale in the Antarctic ecosystem.

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Remote Sensing and Mapping of Debris Covered Ice Masses; Transantarctic Mountains, Antarctica

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In the Transantarctic Mountains (TAM), a limited number of buried ice masses have been discovered. These ice masses are buried underneath < 1 m of till which thermally shields them and limits sublimation thus preserving the ice. An example of such is found in Ong Valley, with sublimation till at >1.1 Ma years old, consequently making it one of the oldest known ice masses on Earth. This ice can yield information on paleoclimate, past atmosphere, and ancient organisms.
In addition to a few known locations, no systematic effort has been made to map such ice masses in Antarctica. This research is motivated by the potential trove of paleoproxies harbored in these ancient ice bodies.
We use remotely sensed imagery (World View) to identify locations for these buried ice masses. The imagery consists of four spectral bands in the blue, red, green, and near-infrared region of the electromagnetic spectrum with sub-meter spatial resolution. The visual detection of landforms associated with buried ice masses combined with digital elevation model allows us to uniquely identify the buried ice masses. To develop and refine our technique we used Ong Valley, Antarctica for ground truthing.
We expect to find a small number of the buried ice bodies which will allow us to study the spatial and elevation patterns. This project has a potential to extend further back in time our understanding of the ice-sheet fluctuations and paleoclimate.

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Thinning history of Byrd and Mulock Glaciers: A preliminary field report

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Response of the West Antarctic Ice Sheet (WAIS) to projected warming remains a significant uncertainty in sea level rise projections. The aim of this project is to provide understanding of past mechanisms and feedbacks of ice sheet retreat, to reduce uncertainty in projections of future change. We will extend the observational record of ice sheets by targeting strategic locations around the margins of the Ross Ice Shelf, where glacial sediments deposited on nunataks next to dynamic ice margins record the transient evolution of the ice surface elevation immediately prior to the observation period. Our cosmogenic surface exposure chronologies from these sites will quantitatively constrain (i) past rates of ice thinning; (ii) total magnitudes of ice elevation change; and (iii) the absolute timing of ice discharge and thinning events in these sensitive regions. Our new ice thinning histories will inform high-resolution, regional-scale numerical glacier model experiments, in which we will determine the surface mass balance and ocean-heat drivers of ice discharge events.

Field work undertaken during the 2019-20 field season focused on outcrops along the Byrd and Mulock glacier catchments. Overall, ~30 samples of bedrock and glacial erratics were collected for cosmogenic surface exposure dating. Main highlights include i) erratic cobbles found at Lonewolf Nunataks indicate that upper Byrd Glacier has previously been at least 250 m thicker than present and ii) Striated bedrock surfaces and glacial erratics found mid-way up Mt. Marvel indicate that Mulock Glacier was previously thicker, and that local flow paths were different to present.

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Presence of Meteoric Beryllium-10 in Miocene Sediments Challenges Permanent Polar Aridity in the McMurdo Dry Valleys

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Many studies suggest that at high elevations, the McMurdo Dry Valleys have remained frozen under a hyper-arid polar climate since ca.12.9 Ma. Ground ice is ubiquitous in subsurface sediments at these elevations, and its presence in sediments dating back to the Mid-Miocene (ca.14 Ma) is at the center of the debate regarding the onset of permanent aridity. Recent studies using met^{10}Be as a tracer for water infiltration in two nearby high elevations sites yield conflicting results. Dickinson et al. (2012) found significant met^{10}Be concentrations down to 4.5 m at Table Mt. (77°57'S, 161°57'E, 1945 m a.s.l) suggesting infiltration of liquid water during warmer periods well after 12.9 Ma, whereas Valletta et al. (2015) did not detect met^{10}Be within 60 cm at Friis Hills (77°45'S, 161°30'E, 1200 – 1500 m a.s.l), supporting persistent polar aridity and opening up a debate on leaching methods. Here, we investigated both sites using the same leaching method as Valletta et al. (2015), measuring met^{10}Be in a 5 m core at Friis Hills and samples from the Dickinson et al. (2012) study at Table Mt. Our results show that met^{10}Be is present down to a depth of 5 m at both sites, in concentrations 2 – 4 orders of magnitude greater than those found by Valletta et al. (2015). These findings show that water infiltration occurred after the emplacement of the sediment, indicating warm and wet periods through the late-Miocene and Pliocene; findings which are supported by the isotopic signature of the near-surface ground ice.

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Understanding the landscape evolution of the Fildes Peninsula (King George Island, Antarctica) through carbon and nitrogen analysis

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Over the last century, the Maritime Antarctica region is suffering because of the global climate change effects. The glaciers are retracting, resulting in more ice-free areas and more soil exposition, which the changes promote influence at the structure and modify the landform. This work shows preliminary data from Fildes Peninsula, King George Island, which correlate the dynamics of the soil and its composition and nutrient content. Analysis of stable isotopes of carbon and nitrogen were carried out in two sediment profiles, in addition to samples of the main sources of sediment and organic matter in the Fildes Peninsula. The results reveal that the values of δ13Corg (-19.3‰ to -21.5‰) and δ15N (-1.4‰ to 4.6‰) are more positive as compared to the soil profile from the Collins Glacier proglacial area (δ13Corg = -20.6‰ to -23.8‰ and δ15N = -3.0‰ to -0.2‰), suggesting a significant influence of marine animals on the carbon and nitrogen contents in the soil. From these findings, a mixture model was applied to understand the influence of the nutrient inputs and the drainage systems in this region in the last thousand years.

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Comparing weathering alteration of sediments from distinct zones of Antarctica: Ellsworth Mountains, South Shetland Islands and Antarctic Peninsula

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This work presents the initial results of geochemical analysis, based upon the interpretations and comparison of lacustrine and terrigenous fine-grained sediments from distinct glaciated and ice-free areas of Antarctica: Ellsworth Mountains (Patriot and Independence Hills, Union Glacier), South Shetland Islands (King George Island and Deception Island), and Antarctic Peninsula (Trinity Peninsula, James Ross Island and Vega Island). Silt samples were analyzed by the Malvern laser light scattering granulometer. The concentrations of major elements were determined by Energy-dispersive X-ray Spectroscopy in <0,062 mm grain-size fraction. The mineralogical composition was determined by X-ray diffraction using Brucker D8 Advance x-ray diffractometer. Chemical Index of Alteration was applied. Initial results point to Chemical Index of Alteration with moderates values between 56.0-73.8 (average – 63) in some sectors of King George Island, but incipient values between 26,3-52,0 in James Ross and Vega Islands (average – 33,9). Incipient values are also observed in the Ellsworth Mountains but are higher in Patriot and Independence Hills (between 11,0-50,8 / average – 32,4) than in Union Glacier (between 1,5-51,2 / average – 27,4). In comparison with continental Antarctica, the South Shetland Islands and some sectors of the Antarctic Peninsula have a higher level of chemical weathering because they have been deglaciated earlier, the temperatures above zero and high summer humidity in the last six decades. Nevertheless, divergent values are found in the same regions, which may infer that the climatic, geological and topographic conditions play an important role in the composition and concentration of the elements in the sediments.

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Sedimentary analysis of Boeckella Lake Bottom Sediment, Trinity Peninsula, North Antarctic Peninsula

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The work will present climatic and environmental information of the deglaciated area of Trinity Peninsula, Antarctic Peninsula, based upon the interpretation of bottom sediment from Boeckella Lake. By the geochemical, mineralogical and isotopic composition of the sediments, in addition to granulometric and morphoscopic analysis, the work will also correlate the results with the temperature rise in the region. Elevated temperatures since the mid-20th-century in the Antarctic Peninsula region have generated extensive ice-free areas, and consequently, more exposed to the atmospheric and erosive events. Lake Boeckella, the largest water body, and former water supply to the Argentine Hope Base had 67.454 m2 and maximum depths between 7 and 9 m, with major contribution of melting water flow, mainly in the summer months, from the snow and Buenos Aires glacier. After two events of overflowing since the 2000s, the lake began to dry up and shrunk in two separated ponds. The lake floor and the past levels became exposed due to the fall in water level, and sediment samples could be collected during the fieldworks in January/February 2019, headed by the Holocene Lakes Project of Argentine Antarctic Program. CAMSIZE analyzer obtains the particle size distribution of sand fractions, and the silt samples are analyzed by the Malvern laser light scattering granulometer. The concentrations of major elements are determined by Energy-dispersive X-ray Spectroscopy, in <0,062 mm particle-size distribution. The mineralogical composition is determined by X-ray diffraction using the Brucker D8 Advance x-ray diffractometer. Chemical Index of Alteration is also applied.

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Environmental magnetic properties of surficial soils from Larsemann Hills, East Antarctica: An Insight into pedogenesis

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It is well-known that topography, time, lithology, organic matter and climate are mainly responsible for the formation of soils. However, in the polar deserts of Antarctica, geomorphic and soil development processes are hindered by a combination of low temperature, low moisture and freezing conditions. In this study, we report the environmental magnetic properties (concentration, mineralogy and grain size) of 67 surficial soils from Larsemann Hills, East Antarctica with an aim to understand pedogenesis. Magnetic susceptibility values for these soils show a wide range of values ranging from 14.59 x 10-8m3kg-1 to 971.27 x 10-8m3kg-1 with an average of 179.83 x 10-8 m3kg-1. The wide range suggests a varied concentration of magnetic minerals in the soils. Soils with high pedogenic magnetic minerals will exhibit high χfd % values. In this study, the χfd % values vary between 0 % and 2.67 % with an average of 0.68 %. The low values suggest the absence of ultra-fine superparamagnetic (SP) grains and that the magnetic signal is largely controlled by the coarse-grained (multi-domain) iron-bearing minerals, which is further corroborated by the S20 (IRM20mT/SIRM) and χARM/SIRM ratios. The average S-ratio value is 0.98, suggesting that these soils have a major proportion of low-coercivity minerals. The strong correlation between χlf and SIRM (r^2 = 0.80) suggests the presence of a high concentration of ferrimagnetic minerals. The low χfd % suggests a low pedogenetic intensity and that the iron-bearing minerals are largely derived due to the physical weathering of the parent rocks.

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The effect of continentality and elevation on erosion rate in Victoria Land, Antarctica

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The extremely cold and dry conditions present in Antarctica minimize the effect of weathering and erosion on the landscape culminating in some of the lowest erosion rates on Earth (Protenga et al., 2011). Previous Antarctic-wide reanalysis of erosion rates shows that latitude, continentality, and elevation do not play a role in controlling the rate of erosion in Antarctica (Marrero et al., 2018). However, the existing data used for reanalysis are heavily biased toward inland, high-altitude areas near the ice sheet. None are within 20 km of the ocean and very few are at low elevation.

We use terrestrial cosmogenic nuclides to determine the differential erosion rate for graywacke using glacially striated quartz veins. These data were collected at low-elevation sites, near seasonally open water in Northern Victoria Land, Antarctica, away from the dominant climatic influences of the ice sheet and large katabatic corridors which funnel cold, dry, sediment starved air from the Antarctic interior.

Our low-elevation costal rates (8.86±0.78 m/Myr and 7.15±0.06 m/Myr) are the highest measured on the continent, while the values 50 km inland at ~500 m elevation show high to average rates (3.38±0.27 m/Myr and 1.08±0.09 m/Myr) for Antarctic conditions. When these new rates are plotted with other reanalysis data from Victoria Land there is a strong negative correlation between altitude/continentality and erosion rate. The presence of an erosion rate gradient is significant for the study of landscape evolution and also when correcting terrestrial cosmogenic nuclide exposure ages on landforms and bedrock used to constrain glacial histories.

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The First Turkish Antarctic Meteorite Search Expedition

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Meteorite recovery expeditions systematically search various areas in Antarctica to recover meteorites from the bare blue ice fields. For instance, the Japanese Antarctic Research Expedition (JARE) and the Belgian Antarctic Expedition (BELARE) joint expeditions recovered more than 900 meteorites in the 2010-2011 and 2011-2012 seasons within the blue ice fields of Nansen ice field. More recently, a daily reconnaissance trip to the Nansen blue ice fields resulted in the recovery of 3 meteorites by the Turkish Antarctic Expedition. Upon recovery, they were given preliminary identification numbers of 190109286, 190109287, and 190109288. Their weights are 7.52 g, 50.68 g, and 6.24 g, respectively. After classification at NASA's Johnson Space Center, these meteorites were discovered to be L and H type ordinary chondrites. Following their classification, the meteorites were given permanent official names (Asuka 18001, 18002, and 18003) according to the guidelines set by the Nomenclature Committee of the Meteoritical Society. The Turkish Meteorite Working Group has established a protocol to store and curate the recovered meteorites upon request after their necessary preliminary investigations. In this presentation, we will report results of our recent laboratory work in the recovered meteorites as well as the expedition details.

SCAR 2020

Antarctic Science - Global Connections

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SESSION 13

ANTARCTICA AND ITS NEIGHBOURS IN SUPERCONTINENT CYCLES

Jacqueline Halpin

Nathan Daczko, Laura Morrissey, Geoff Grantham

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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The tectonic stress field evolution of Tasmania since the Cenozoic

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The separation of the Australian Plate with respect to the Antarctic Plate during the Cenozoic was the origin of the development of the Tasmania Passage. In order to better understand how the continental fragmentation and the plates drift occurred, it is important to establish the stress orientation and regime that have acted during the formation of this passage. With the aim to contribute to the knowledge of the tectonic evolution of the Tasmanian Passage, approximately 1000 faults distributed in 44 sites located in rocks of ages between the Cambrian and the Quaternary have been measured in Tasmania. The fault population analysis has been carried out using the methods of Etchecopar, y-R, Right Dihedral and Stress Inversion. The fault orientation analysis shows a predominant orientation ESE-WNW and secondary directions NE-SW, NW-SE and N-S. Considering the faults movement sense, 313 dextral, 194 sinistral, 422 normal and 62 reverse faults have been identified. Dextral faults show an ESE-WNW orientation. Sinistral faults have a predominant orientation N-S. The most of the dextral and sinistral fault planes dips are subvertical. Normal faults have a main NW-SE orientation and a NE-SW secondary direction with a modal dip value of 65°. Reverse faults have a predominant NE-SW direction with two modal dip values of 35° and 70° respectively. The $\sigma 1$ orientation shows a dominant NW-SE direction. Moreover, another common stress regime is characterized by a preferentially NE-SW $\sigma 3$ orientation (with $\sigma 1$ vertical). The σy direction is dominantly NW-SE, although it shows a secondary mode with NE-SW orientation.

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What is Under the Antarctic Ice: An Integrated Study of U-Pb, O and Lu-Hf Isotopes

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Antarctica is a central piece in the Gondwana supercontinent jigsaw, connecting Australia, India and Africa. Bedrock exposure in Antarctica is sparse with over 98 % of the continent covered by ice. Understanding its geology can reveal the correlations between Antarctica and its neighbours and elucidate its role in the amalgamation and breakup of the Gondwana supercontinent.
Detrital zircons separated from IODP holes drilled around Antarctica have been analysed for U-Pb, O and Lu-Hf isotopes. U-Pb results show major detrital zircon crystallization peaks at ca. 70, 500, 1100 and 1750 Ma. The later three correlate with peaks in the Australian detrital zircon population. The largest ca. 500 Ma peak is interpreted to represent zircons derived from the Transgondwana Supermountain formed by the collision between East and West Gondwana. Unlike studies based on $^{40}Ar/^{39}Ar$ dating from hornblende and biotite, the ca. 70 Ma peak is significant. It was produced by extensive late Mesozoic arc magmatism in West Antarctica during the separation of South America and the Antarctic Peninsula.
$\delta^{18}O$ values of ca. 500 Ma group from Antarctica cover a large range (4.9-11‰), similar to the range of $\delta^{18}O$ in ca. 500 Ma detrital zircons from Australia. Zircons of ca. 70 Ma from West Antarctica are unusual and have $\delta^{18}O$ less than the mantle value, implying crystallization from a felsic magma by melting wet basalt. Lu-Hf isotopes of detrital zircons from Antarctica will be compared with those from the Australian continent and used to constrain the geological correlation between the Antarctica and Australia.

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Complex zircon and monazite geochronology, East Antarctica: experiments and nature

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East Antarctica is well known for rocks that exhibit complex geochronology; data spreads close to concordia over tens to hundreds of Myr. Traditionally, the oldest analyses are used to infer the age of igneous crystallisation or a high-T metamorphic event, whereas the youngest ages point toward the timing of a Pb-loss event. While the isotopic and trace element characteristics of zircon and monazite have been well characterised, clear links to microstructural patterns are often lacking. Our study presents new data for gabbroic melt-zircon and granitic melt-monazite reaction experiments and compares the compositions and textures of the reaction products to those of natural samples from East Antarctica.

The experiments resulted in a range of complex textures that are attributed to both dissolution and coupled dissolution-precipitation (CDP) processes. The microstructure and complex age patterns of natural zircon and monazite from a range of rocks of East Antarctica are comparable to the modified grains in our experiments.

We interpret the complex textures and age-data patterns of East Antarctic zircon and monazite grains as the result of melt-mediated coupled dissolution-precipitation reactions acting on pre-existing zircon and monazite grains. This process skews apparent ages towards the age of melt-mineral interaction. We therefore place significance on the youngest grains to date high-T anatectic events. We highlight that zircon and monazite grains modified via coupled dissolution-precipitation may not faithfully record the age or duration of metamorphism in melt-present systems and caution against relying on complex data sets for such interpretations.

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Cenozoic continental rifting in the north-western Ross Sea.

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The north-western region of the Ross Sea has been subjected to three main extensional events during the Cenozoic. The older (61 – 53 Ma) rifts of Central Basin and Central Trough occur to the east. The deep water (2000m) of the Central Basin in the north separates the Iselin Bank from the western Ross Sea continental margin, and gravity modelling indicates a thin crust (basement ~8km) with sharp margins, probably oceanic, underlying its central part. The rift continues south into the continental Central Trough graben. A stage pole of rotation was derived for this extension based on limited magnetic data and estimates of extension for the basin/trough. The Transantarctic Mountains form the western rift margin of the Ross Sea and traverse Antarctica, separating East from West Antarctica. They were primarily uplifted about 55 – 45 Ma, between the times of the extension episodes forming Central Basin and Northern Basin, along a major lithospheric boundary, but no extension estimates are available. New ocean crust formation (43 – 26 Ma) in the Adare Basin off north-western Ross Sea can be traced using magnetic data directly into the Northern Basin underlying the adjacent continental shelf, implying a continuity of emplacement of oceanic crust. Steep gravity gradients along the margins of the Northern Basin suggest that little extension and thinning of continental crust occurred before it ruptured and new oceanic crust formed, unlike other continental rifts. Estimates of extension enables the restoration of Iselin Bank back to the Transantarctic Mountains.

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The AIRLAFONIA survey: new plate kinematic constraints on Mesozoic tectonics in west Antarctica

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We present the results of a recent aeromagnetic survey over the Falkland Plateau Basin. Magnetic reversal isochrons in the east of the basin reveal Jurassic-onset seafloor spreading. The basin's thick igneous crust further west also formed in Jurassic times, but in a subaerial setting. These isochrons can be reconstructed to likely conjugates in the southwestern Weddell Sea, suggesting the Falkland Plateau Basin and earliest Weddell Sea formed in a back-arc setting by divergence of a newly-recognized plate, named after the Skytrain Ice Rise, from West Gondwana. The growth of this Weddell-Falkland Plateau ocean at the Skytrain-West Gondwana plate boundary generated a barrier of oceanic lithosphere across what was to become the Drake Passage gateway, adding to previous observations that suggest correlation-based interpretations of the South Georgia microcontinent's Eocene-and-later translation from the Pacific margin of Gondwana should be regarded as untenable. Further south in the Weddell Sea Embayment, aeromagnetic and outcrop evidence for rifting confirms the plate circuit's requirement for Skytrain to have diverged from East Gondwana in mid-to-late Jurassic times. The circuit requires Skytrain and East Gondwana to have subsequently collided early in the Cretaceous. This setting contextualizes and more precisely constrains the timing of post-Cambrian paleomagnetic rotations from the Ellsworth mountains, as well as thermochronological and structural observations of their Cretaceous uplift and post-Permian oblique-dextral collision. In contrast, the Skytrain Plate concept does not allow for large-scale rotation of the Falkland Islands during Gondwana breakup, as has long been proposed on the basis of paleomagnetic and geological correlation studies.

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Comparing the build-up of East Antarctica to its former Gondwana neighbours

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Numerous unresolved issues exist regarding the lithosphere of (East) Antarctica, especially in terms of density, temperature, and compositional structure. Estimates of total lithospheric thickness often involve assumptions on the depth of the Moho discontinuity, which is subject of high uncertainty in Antarctica. Recent estimates of the Moho depth from different geophysical methods show significant discrepancies of up to 10-20 km. While seismological methods suffer from a limited station coverage and ice reverberation, potential field methods, such as gravity studies, are inherently non-unique.
Here, we compare recent global lithospheric models that account for thermodynamically stable mineral phases of rocks under in-situ pressure and temperature conditions, for East Antarctica and its formerly adjacent Gondwana neighbours. The integrated modelling compensates for the sparseness of data in Antarctica and reduces inconsistencies and ambiguities of separate geophysical methods to a large extent. We compare the global models with a dedicated Antarctica model, where gravity gradient data from ESA's satellite mission GOCE have been used to constrain the density distribution within the lithosphere in an integrated 3D model. The presented model includes new estimates of the crustal and the total lithospheric thickness of Antarctica.
Furthermore, we make use of newly processed aeromagnetic surveys to describe the crustal structure in a Gondwana setting. This approach helps to describe the tectonic setting in order to derive parameters like geothermal heat-flow, especially if combined with statistical methods like machine learning.

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Unveiling cryptic imprints of rifting, magmatic arcs and accretion in East Antarctica linked to subduction of Nuna's oceans

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East Antarctica is a key missing piece of the puzzle to reconstruct global supercontinent cycles. However, what happened to East Antarctica during the assembly and growth of the Nuna supercontinent between the Paleoproterozoic and the Mesoproterozoic remains particularly poorly understood. To address this major knowledge gap, we present and interpret new continental-scale aeromagnetic and aerogravity data compilations, and satellite gravity and satellite magnetic imaging, complemented by passive seismic and geological data and modelling. This enables us to re-define the extent and the architecture of several major crustal provinces in interior East Antarctica. We delineate a narrow and elongated Archean ribbon microcontinent (proto-Mawson) that connects exposures of Archean basement in Terre-Adélie and the Central Transantarctic Mountains. We propose that proto-Mawson is flanked by a rifted Paleo to early Mesoproterozoic Wilkes Terrane to the east, and several distinct Paleo to Mesoproterozoic magmatic arcs of inferred continental margin and oceanic affinity respectively to the west. By incorporating geophysical, geological, geochronological and paleomagnetic constraints, we then embed our new geophysical views for East Antarctica into GPlates to obtain a new kinematically evolving Nuna plate reconstruction. Several key aspects of our Nuna reconstruction have variable degrees of speculation attached, but we contend that our hypotheses could be further tested by targeted future studies, including drilling. Overall, our new interpretations support the hypothesis that a large tract of East Antarctica was built during long-lived subduction of Nuna's exterior ocean, following the closure of a smaller interior ocean that separated proto-East Antarctica and Australia from Laurentia.

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Crustal architecture of a large pull-apart basin in East Antarctica unveiled

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Here we combine aeromagnetic, aerogravity, land-gravity and bedrock topography imaging to help constrain the extent, architecture and kinematics of the largest Cenozoic pull-apart basin recognised so far in East Antarctica, the Rennick Graben (RG).
Enhanced potential field imaging reveals the extent of part of a Jurassic tholeiitic Large Igneous Province preserved within the RG and the inherited structural architecture of its basement, including remnants of uplifted ca 530-500 Ma arc basement in the northern Wilson Terrane and a ca 490-460 Ma subglacial thrust fault belt that separates the Cenozoic western flank of the RG from the eastern margin of Wilkes Subglacial Basin (WSB).
The RG is interpreted here as a major composite right-lateral pull-part basin that extends from the Oates Coast to the Southern Cross Mountains block. We propose that Cenozoic strike-slip deformation kinematically connected the RG with the western edge of the West Antarctic Rift System and the eastern margin of the WSB.
We conclude that the RG is part of a wider and more distributed region of the continental lithosphere in East Antarctica that was deformed in response to an evolving Cenozoic transtensional tectonic setting that may have also affected enigmatic sub-basins such as the Cook Basins within the adjacent WSB.

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New magnetic and gravity views of Precambrian and Pan-African age crustal features between Dronning Maud Land, Shackleton Range and South Pole

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By analysing aeromagnetic, aerogravity and satellite gravity and satellite magnetic images we investigate crustal architecture and identify some of the key tectonic and magmatic features within the basement located between Dronning Maud Land, Shackleton Range and South Pole. Our findings provide a new glimpse into the tectonic and geodynamic processes that affected East Antarctica from Nuna, Rodinia and Gondwana times.

Several Precambrian terranes outcrop within the Shackleton Range, namely the Southern, Northern and Eastern terranes. The Southern Terrane in particular includes an exposed belt of juvenile Paleoproterozoic crust and a prominent aeromagnetic and satellite magnetic anomaly is interpreted as reflecting the roots of a Paleoproterozoic arc-related ribbon terrane.

Completely different magnetic and gravity signatures occur north of the Shackleton Range suture over the Coats Land Block, which are broadly comparable e.g. to the Paleoproterozoic Yavapai Province in Laurentia. Rift-related Keweenawan-age (ca 1.1 Ga) igneous rocks are exposed in small coastal outcrops within this crustal block but our new aeromagnetic images suggest they are widespread also further in the interior.

Arcuate magnetic anomaly belts extend from Dronning Maud Land to the northern margin of the Coats Land Block and also further south beneath the Recovery catchment. These anomalies may reflect belts of accreted Grenvillian-age arc crust, similar to remnants entrained in the Namaqua-Natal and Maud orogenic belts. These and other Precambrian terranes appear to have deformed into complex orocline-like structures bounded by major shear zones, likely linked to Pan-African age orogenic processes associated with protracted East- West Gondwana amalgamation.

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The active triple junction in the NE Antarctic Peninsula: new insights from NE Bransfield Strait and Elephant Island recent tectonic evolution

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The northern margin of the Antarctic Peninsula is affected by the most recent tectonic activity related to the last stage of the opening of the Drake Passage. The subduction along the South Shetland Trench of the Former Phoenix Plate, now belonging to the Antarctic Plate, contributes to the detachment of the continental South Shetland Block from the Antarctic Peninsula and the development of the Bransfield Basin. The underthrusting of the active transpressive sinistral Shackleton Fracture Zone below this continental block shaped the active triple junction that determined the NE tip of the South Shetland Trench and the uplift of Elephant Island. This geological context produced changes in tectonic regime along the NE Antarctic Peninsula, including transcurrence associated to the Shackleton Fracture Zone, compressive deformations with reverse faults and large open folds related to subduction in the northern part of South Shetland Block and Elephant Island and extensional processes in Bransfield back arc basin and the southern part of Elephant Island. The analysis of the recent structures from multichannel seismic profiles, detailed bathymetric data, seismicity including earthquake focal mechanisms and paleostresses determined from mesofault population analysis, improves the knowledge of the recent tectonic evolution of the triple junction and highlights implications on the latest palaeoceanographic evolution of the Drake Passage.

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Results of ground magnetic surveys and petrophysical studies in the Bunger Hills, East Antarctica

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Ground surveys during 2017-20 seasons in the Bunger Hills completed by PMGRE and VNIIOkeangeologia acquired more than 320 line-km of magnetic data. The petrophysical data set representing the study area comprises c. 600 samples, collected for the follow-up of magnetic anomalies during field trips, and also in situ susceptibility measurements were made in selected areas. The major goal of these studies was to clarify the magnetic image of the Paz Cove batholith at its boundary with basement rocks.
The banded magnetic patterns with high-gradient zones throughout the boundary of the Paz Cove batholith are mainly associated with a finely interlayered sequence of orthopyroxene-bearing tonalitic orthogneiss and predominantly garnet–cordierite ± sillimanite gneiss, with minor psammitic gneiss and other rocks. This was verified by susceptibility measurements, when migmatized and mylonitised orthogneiss and schists have high magnetizations with the average susceptibility value of about 34.3×10-3 SI, whereas paragneiss of roughly 0.32×10-3 SI. Among metagabbroic rocks of the compositionally varied Paz Cove batholith monzodiorites, diorites and gabbrodiorites yield modal susceptibility value of the order of 25.1×10-3 SI, and monzogabbroids and gabbroids are less magnetic with susceptibilities of about 4.04×10-3 SI, when blastomylonitic gabbroids show susceptibilities in the range 1.1-103×10-3 SI with modal value 11.6×10-3 SI. High magnetization of the Paz Cove plutonic rocks does not correlate with the observed magnetic anomaly pattern which exhibit predominantly negative anomalies with amplitude up to –1490 nT and possibly affected by their strong remanent magnetization. The most intense negative anomalies are associated with quartz-bearing monzodiorites and granodiorites.

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Investigating Princess Elizabeth Land Provinces with new magnetic compilation.

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The total amount of the Russian high-quality aeromagnetic data recently collected over Princess Elizabeth Land (PEL) exceeded more than 70,000 line-km. They clearly depict the extent of tectonic belt characterised by low amplitude, linear/curvilinear NE-SW-trending magnetic anomalies that is extremely straightforward relative to the other regions of East Antarctica. At the eastern shoulder of the Lambert Rift they are associated with orthogneissic Pickering Series and paragneissic Manning Series. Based on U-Pb zircon ages and chemical comparisons, these rocks are nearly identical to those of the Beaver Complex. The most outstanding Robertson anomaly is reflected by amphibolite-facies rocks only occur in Robertson Nunatak where mafic schists and orthogneiss crop out. Isotopically juvenile rocks from the Fisher Terrane and Robertson Nunatak may represent a small-scale oceanic arc extending eastward across the Lambert Rift. Two fragments of this oceanic arc displaced approximately 50-60 km along dextral strike-slip system of faults are most likely related to Cretaceous transtensional tectonics. At the Manning Nunataks, mafic granulites can be related to metamorphism of island arc basalts, whereas the felsic volcanic arc orthogneisses have no obvious relation to subduction of oceanic crust. Protolith ages range from ca. 1347 to 1020 Ma, indicating the Rayner continental arc was a long-lived site of crustal accretion. Thus, aeromagnetic surveying over PEL has imaged a distinctive Stenian-aged accretional orogen in East Antarctica. The orogen can be traced uninterruptedly from the Clemence Massif to the southern margin of the Rauer-Vestfold Hills crustal block and further eastwards to coastal areas at 88° E.

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Post ADMAP-2 surveys – new results and achievements

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Since the release of ADMAP-2 map in 2017, the Antarctic geomagnetic community has been very active acquiring more than 550 000 line-km of new air- and shipborne data. Many of these new data sets were obtained by multidisciplinary projects that also acquired airborne laser altimetry, radio echo sounding, and gravity anomaly data for comprehensive studies of the surface, thickness, and internal features of the ice sheets and the subglacial geology and hydrology. Major target of the new surveys was ADMAP-2 gaps coverage such as over Princess Elizabeth Land, the Recovery Basin, the Ross Ice Shelf, the South Pole region, and over other poorly explored Antarctic areas. At present many of new surveys are not publicly available and cannot be combined with previous datasets, but potentially they may provide most important new data for improving the ADMAP compilation and as a result give new views into the large-scale crustal architecture of East Antarctica and its supercontinental linkages. For instance, the Russian aeromagnetic surveying over Princess Elizabeth Land has imaged the extent of distinctive Stenian-aged accretional orogen in East Antarctica. Whereas new aeromagnetic data collected by AWI/BGR surveys from southern and eastern Sør Rondane and their integration with surface geology offer new insights regarding the southern and eastern extents of the Tonian Oceanic Arc Super Terrane. Mapping of magnetic anomalies by the ROSETTA-Ice survey reveals a key break between cratonic East Antarctica and accreted crust of West Antarctica.

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Antarctica in Supercontinent evolution - Rodinia to Gondwana Breakup

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The definition of lithologies typically associated with plate margins in Rodinia and Gondwana permits the definition of continuous geological provinces contributing to the recognition of continental crustal blocks within and pre-dating reconstructed Gondwana.

These data along with aerogeophysical data from Antarctica, combined with geochronological and structural data permit the recognition that the Kuunga and Ross Orogenies define two broadly parallel plate margins involved in the amalgamation of Gondwana between ca. 650Ma and ca. 480Ma.

The Ross Orogeny is recognised as involving an arc subduction setting stretching from South America, through the Cape (Southern Africa), Transantarctic Mountains to eastern Australia.

In contrast the Kuunga Orogeny involved a continent-continent collision setting (post dating the East African Orogeny) between North and South Gondwana extending from the Damara Belt (Namibia), through the Zambesi and Lurio Belts (Zambia and Mozambique), through Sri Lanka into East Antarctica. Further extensions are possible south of Enderby Land through the Prince Charles Mtns area to Princess Elizabeth Land to western Australia. This orogeny has contibuted to much of East Antarctica being underlain by a block of double-thickened crust, reflected in gravity studies, which contains a broadly uniform aeromagnetic linear fabric extending from western Dronning Maud Land to the Gamburtsev Mtns and beyond.

The central Antarctic crustal block formed during the Kuunga Orogeny would provide a relatively proximal source for the extraordinary extensive sandstone sequence extending from the Cape Fold belt in the west, via the Transantarctic Mountains to eastern Australia.

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Neoproterozoic to Cambrian granitoids of northern Mozambique and Dronning Maud Land Antarctica: Implications for the assembly of Gondwana during the Kuunga Orogeny.

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The field relationships, petrography, whole rock major, trace element and radiogenic isotope chemistry and geochronology of Cambrian Granites from the Nampula Terrane (NT) Mozambique are reported. These data are compared with published data from Neoproterozoic to Cambrian granites from Central Dronning Land (CDML) and the Cabo Delgado/Namuno Terrane of northern Mozambique (CDNT). The CDML and Nampula terranes are contiguous in reconstructed Gondwana. Whereas there is significant overlap in the chemistry and ages of the granites from the Nampula Terrane compared to those from CDML and CDNT, indicating their probable genesis within the same broad orogenic event, subtle differences in distribution, mineralogy, chemistry and age are seen. These differences include subsolvus peraluminous mica-dominated granites with ages <~530 Ma in all three areas but concentrated in the Nampula Terrane. This in contrast to the dominantly metaluminous hypersolvus charnockitic syenogranites with ages >~530 Ma restricted to CDML and CDNT terranes. The differences between the two granite varieties are inferred to reflect differences in tectonic setting during orogenesis and genesis with the marginally older CDML and CDTNM granites resulting from decompression dehydration melting of amphibole in an extensional setting restricted to the hanging wall of a mega-nappe. In contrast the marginally younger granites were generated from dehydration melting of mica in the footwall of a to-to-SE directed mega-nappe structure during the Kuunga Orogeny but emplaced into both floor and roof complexes.

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The Kuunga Nappe of Sverdrupfjella, western Dronning Maud Land, Antarctica.

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The geology of Sverdrupfjella, western Droning Maud Land, Antarctica comprises three complexes. The ~1140Ma Jutulrora Complex consists mostly of arc-related TTG orthogneiss with evolved Sr/Nd isotopic signatures with TDm ages >2by. The Fuglefjellet Complex, structurally overlying the Jutulrora Complex, comprises supracrustal (~800-900Ma) carbonates intercalated with ~1100-1200Ma quartzo-feldspathic gneisses with ca. 500Ma metamorphic overprints. The Rootshorga Complex, structurally overlying the Fuglefjellet Complex, contains paragneisses with minor ~1100-1200Ma orthogneisses, intruded by granitic orthogneiss of similar age. Sr/Nd isotopic signatures from the Fuglefjellet and Rootshorga Complexes have TDm ages <1.8by. D1 and D2 deformation verges top-to-NW. In contrast D3 deformation verges top-to-the-SE. In the Jutulrora Complex, D3 is characterized by ~100m scale folds with NW dipping axial planes cut by SE dipping dilational granite sheets. In the Rootshorga Complex D3 is characterised by syntectonic dilational granite sheets with extensional and compressional displacements with top-to-the SE shear. Zircon ages of the granitic sheets are 490-500Ma. Sr/Nd isotopic signatures of the granitic sheets which intrude all complexes, are consistent with melting of crust similar to the Jutulrora Complex with Archaean and Mesoproterozoic xenocrysts seen in some samples. P-T-t studies from the Rootshorga Complex yield an ITD path with decompression from ~1.4Gpa at ~570Ma to ~0.7Gpa at ~500Ma whereas P-T-t estimates from the Jutulrora Complex are <~0.8Gpa at ~500Ma with a path consistent with crustal loading. The Rootshorga and Fuglefjellet Complex are inferred to comprise a mega-nappe, emplaced during the Kuunga Orogeny ~500Ma ago, over the footwall Jutulrora Complex. Geophysical data are consistent with this interpretation.

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New geochemical data from central Dronning Maud Land: Implications for Gondwana reconstruction.

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The western Mühlig-Hoffman Mountains and the area around Gelsvikfjella in central Dronning Maud Land, East Antarctica can provide important information to the understanding of the assembly of the Gondwana Supercontinent. Rocks in this area comprise a polyphase deformed and metamorphosed assembly of Mesoproterozoic ortho-gneisses with minor supracrustal components and mafic bodies which were reworked during the late Neo-Proterozoic East-African Orogen and subsequent Kuunga Orogen and intruded by large volumes of post tectonic A-type granites of Cambrian age. In addition, the area has been intruded by multiple phases of syn- to post-tectonic felsic veins which remained poorly studied until now. This study aims to provide a comprehensive geochemical survey of all rock types in the area but in particular the felsic veins through the analysis (major, trace, REE and Nd-Sr isotopes) of 68 samples. The majority of basement rocks plots in the monzogranite – granodiorite field with the mafic rocks classifying as syeno-monzo-grabbro and gabbro. All the felsic veins (27 samples) plot as granite, however, results indicate that these rocks are subdivided into two geochemically distinct groups. This distinction is supported by structural data, cross-cutting relationships and differences in isotopic signatures suggesting two possible different sources not related to host country rocks and pointing to older and deeper sources. The new geochemical data sheds light on the petrogenisis of the late felsic veins which could play an important role in the understanding of the final stages of collision in Central Dronning Maud Land where current theories are inconsistent and conflicting.

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Age, affinity and architecture of basement to the Bruce Rise, Wilkes Land, East Antarctica

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The Bruce Rise is a prominent bathymetric feature offshore the Bunger Hills in Wilkes Land, East Antarctica. In East Gondwana, the Bruce Rise is reconstructed near the Naturaliste Plateau (offshore SW Australia) and microcontinents now submerged in the eastern Indian Ocean (Batavia and Gulden Draak knolls). We investigate the age and affinity of two Bruce Rise granitic rocks dredged from a steep eastern escarpment onboard the R/V Hakurei-Maru.

The zircon U-Pb-Hf data are complex and dominated by xenocrystic cargo with ages of c. 1590 Ma, 1500 Ma and 1270 Ma. Xenocrystic cores show textural evidence of melt-mediated coupled dissolution-precipitation to form rim domains with apparent ages that skew towards c. 1190-1150 Ma. We suggest that c. 1150 Ma is the likely crystallisation age of both samples.

The zircon U-Pb-Hf signatures from the Bruce Rise granites, and from c. 1230 to 1180 Ma granites and orthogneisses from the conjugate Naturaliste Plateau, suggest that late Mesoproterozoic magmatism occurred at a transition in the Australo-Antarctic tectonic architecture between a reworked Archean cratonic margin and Proterozoic juvenile crust.

Basement to the Bruce Rise and Naturaliste Plateau was extended and exhumed during the rifting of India from East Gondwana (prior to c. 120 Ma). Onshore NW-trending basement faults in Antarctica are subparallel to offshore bounding fracture zones, suggesting an array of favourably oriented basement structures played a role in the early evolution of this extended margin. Minor further thinning likely occurred leading up to the onset of seafloor spreading (from c. 90 to 84 Ma).

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Antarctica in Gondwana and earlier Supercontinents: Evidence from the Rauer Islands, Prydz Bay

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The Rauer Islands is critical to interpretations of the assembly of east Gondwana and links between eastern India and Antarctica. The Rauers preserve a punctuated geological record spanning from 3.5 Ga to 0.5 Ga, including high-grade tectonothermal events that broadly correspond in timing to global supercontinent episodes and recently have been proposed to correlate with events recorded in the Rengali Province of India.
The Archaean of the Rauers features 3.5 Ga, 3.3 Ga and 2.8 Ga TTG gneisses, and 3.3 Ga and 2.8 Ga layered mafic-ultramafic metaigneous complexes. Mesoproterozoic granitic to dioritic intrusives were emplaced at 1 Ga into a Fe-Al pelites and metabasites, the Filla Supracrustals, derived from older Proterozoic sources and deposited prior to 1.06 Ga. A 1.03-0.96 Ga granulite facies tectonothermal event preserved in the Filla Supracrustals is not recorded in the Archaean orthogneisses with which they are now interleaved. 0.58 Ga Ultrahigh-temperature (UHT) metamorphism is uniquely preserved in the Mather Supracrustals. The 0.53-0.51 Ga Prydz Tectonic Event is the only high-grade tectonism shared by all rock units. Hence, this transpressional event resulted in the assembly of the polycyclic crustal units, so that like the Rengali the Rauers is an amalgam of units sandwiched between an Archaean craton to the north and a late Mesoproterozoic to Neoproterozoic collisional belt to the south. However, the constitution of the Archaean, the timing of the Mesoproterozoic tectonism, and the unique presence of 0.58 Ga UHT metamorphism point to the Rauers being distinct from, rather than an extension of, the Rengali.

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Structure of East Antarctica revealed by Connecting Geology & Geophysics: the Dronning Maud Land perspective

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Dronning Maud Land in East Antarctica is a key area for unravelling the protracted assembly of East Antarctica and Gondwana in late Neoproterozoic/early Paleozoic times. Integrating geophysics with geology, and specifically geochronology, reveals the complex tectonic history of East Antarctica that appears to consist of at least seven cratons and cratonic fragments that amalgamated along a network of Grenville-age and Pan-African orogenic belts. Extensive juvenile crustal additions and remnants of the Neoproterozoic Mozambique Ocean are exposed in central to eastern Dronning Maud Land, which can be traced underneath the ice for a considerable distance by geophysical means. Glacial moraine studies confirm the extent of the large extent of juvenile Neoproterozoic crustal additions. This region has the size of present day Antarctic Peninsular and resembles the Arabian-Nubian-Shield farther north along the East African-Antarctic Orogen; it is underlain by thick continental crust. In this contribution, we also provide spatial estimates of pre-Neoproterozoic crustal blocks of African, Indo-Antarctic, Australian and Laurentian heritage and investigate the path of Pan-African mobile belts and their suture zones across East Antarctica from a Dronning Maud Land perspective.

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Geochemistry of basalt pebbles from short sediment drill cores beneath the Ekström Ice Shelf, East Antarctica: Evidence of the Explora Wedge?

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There is evidence that the Explora Wedge basalts, a counterpart to the Jurassic Karoo volcanism in southern Africa, outcrop at the sea floor beneath the Ekström Ice Shelf, Dronning Maud Land, Antarctica. In preparation for a geoscientific deep drilling campaign to further investigate the Explora Wedge and the overlying Meso-/Cenozoic sediments, pre-site surveys were conducted comprising seismic reflection surveying and surface sediment coring through hot-water drilled access holes. Recovered surface sediment cores contained pebbles of 0.5¬-10cm in size, which potentially provide information about the Explora Wedge and the upstream pre-glacial material eroded from the continent.

The large-sized pebbles consist of basalt/dolerite, serpentinite, siltstone, granite and gneiss. Thin-section microscopy of the smaller pebbles revealed mainly basaltic material and minor sedimentary fragments. Geochemically, the basaltic pebbles can be divided into four groups on their (Low/High) Ti and Zr contents: LTHZ1, LTHZ2, HTZ, LTZ. The latter two resemble the high and low Ti-Zr Karoo basalts from central Lembobo (S-Africa; Sweeney et al. 1994). However, while HTZ overlaps with the Southern-Karoo group of Luttinen (2018), the LTZ has higher Nb content. Groups LTHZ1 and LTHZ2 differ from Karoo basalts by their very high Zr and low Ti contents. LTHZ1 resembles the Group 4 basic dykes from Ahlmannryggen (Dronning Maud Land; Riley et al. 2005). LTHZ2 stands out through its extremely high Zr and Nb values and could not yet be correlated.

Luttinen (2018) Nature Sci Rep 8, 1-11
Sweeney et al. (1994) J Petrol 35, 95-125
Riley et al. (2005) J Petrol 46, 1489-1524

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Geochemical and geochronological features of the formation of the earliest crust in East Antarctica

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The nature of the Earth's earliest crust is a subject of ongoing investigation. Gneisses of the Tula Mountains in the Napier Complex of Enderby Land and from the Aker Peaks of Kemp Land reveal some similarities in crustal development through geochemistry and geochronology. These rocks in both areas were metamorphosed at ca. 2.5 Ga during ultra-high temperature (UHT) metamorphism, with an additional ca. 2.8 Ga and ca. 3.6 Ga events identified locally. These events affect magmatic protoliths which were formed before 3.6 Ga, as revealed by new 207Pb/206Pb ages >3.6 Ga (Eoarchean). Orthogneisses from Tula Mountains were geochemically subdivided into Y-HREE-Nb-Ta depleted and undepleted groups, with geochemical diversity demonstrated in Eoarchean protoliths. This indicates that during the Archean, various sources and processes were involved, including re-melting and recycling of various crustal components. The identification of Eoarchean crust in both, Enderby and Kemp Land, at localities around 300 km apart, may be an indication that such crust is widespread around the complex. Like other Archean cratons, the Napier Complex is likely to represent a composite of continental crust formed at different times during the Archean assembled as late as 2.5 Ga.

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Tectonic Map of Antarctica, 2-nd edition

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A 2-nd edition of tectonic map of the Antarctic at 1:10M scale was compiled in VNIIOkeangeologia under the auspices of the Commission for the Geological map of the World. It is significantly upgraded in comparison with the 1-st edition published in 2012. The map shows the tectonic composition of the Antarctic with major crustal types (oceanic, transitional and continental) and their specific structural assemblages and features in geodynamic context. Structural assemblages on the Antarctic continent are underlain by unstrecthed and strethed continentasl crust and grouped in 4 major units: 1) Proterozoic and Phanerozoic accretional fold belts (including subduction and/or collision-related orogenic complexes and for-arc and intra-arc basin complexes); 2) platform covers; 3) intraplate fold systems (variably deformed supracrustal complexes and molasses); 4) intracontinental and marginal rift basins. The separate block of the legend includes archean continental protocrust lacking clear plate tectonics markers. Units in each block are distinquished by colors. Geodynamic environments of igneous rocks and structural features, such as subduction-related and/or intraplate magmatism, faults, thrusts, rifts, etc. are shown by different signs/hatchings which are explained in the Legend. Oceanic crust is mapped depending on its age defined by magnetic lineations. The main map is accompanied by a generalized view of Antarctic tectonic provinces which show the presumed distribution of ancient (Archean) domains, orogenic belts, platform covers and other tectonic features under the ice as well as rates of sea-floor spreading and areas with thickened oceanic crust in the Antarctic seas. The work was supported by the RNF project 16-17-10139.

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Glauconitization episodes before the onset of Antarctic glaciation

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The environmental changes leading up to the first continent-wide glaciation of Antarctica during the Eocene-Oligocene Transition (EOT) is still not fully understood. Declining atmospheric CO2 concentrations and associated feedbacks have been invoked as underlying mechanisms, but the role of the coeval opening/deepening of Southern Ocean gateways, and subsequent changes in paleoceanography remain poorly understood. Evidence suggests both a temperate late Eocene and cooling before the EOT, both broadly coetaneous with a wide, supra-regional diagenetic event that resulted in green-clay (glaucony) formation in the marine realm around Antarctica. Glaucony is a sensitive marker of sedimentation rates, sea-level and sediment physico-chemical conditions, and thus a powerful tool for marine sedimentological and climatic interpretation. In spite of all, the nature, depositional setting, paleoenvironmental implications and chronology of the late Eocene glaucony reported in diverse shallow-marine settings are loosely constrained. Here, we evaluate the palaeogeographic implications and temporal variations of Antarctic glaucony-bearing sediments deposited before major ice sheet advance during the EOT. In this sense, the morphological, mineralogical and geochemical features of late Eocene glauconitized fecal pellets in both ODP Site 696 and Seymour Island sections denote an autochthonous origin of the evolved glaucony grains, indicating a period of low sedimentation rate associated with rising sea levels related to plate reorganization and opening/deepening of Drake Passage.

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Volatile and rock chemistry integration helps deconvolve sources of volcanism in Southern Victorialand

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Formed following the breakup of Gondwana, the West Antarctic Rift System is associated with several magmatic provinces along the rift margins, including the Erebus Volcanic Province (EVP). Multiple sources of the highly alkaline, rare-earth element enriched lavas of the EVP have been hypothesized, including mantle plume(s), melting of a fossilized plume head, and mixing of recycled oceanic crust with one or more enriched mantle sources from the deep mantle. However, the ability to determine a unique source of volcanism in this region has proven to be particularly difficult using traditional methods. Though major element chemistry, trace element chemistry, and radiogenic isotopes (e.g., Sr, Nd, and Pb) are commonly used to delineate magma sources, these elements are readily recycled between the crust and the mantle, and their concentrations and isotopic compositions can change with the degree of partial melting. In contrast, noble gases are chemically inert, have well-characterized and externally defined endmembers, and are not recycled between the crust and mantle, making them reliable tracers of subsurface fluids. Here, we present noble gas isotope ratios (e.g., $^{3}He/^{4}He$, $CO_2/^{3}He$, $^{40}Ar/^{36}Ar$, $^{40}Ar^{*}/^{4}He$) along with trace element chemistry for a suite of lavas in the EVP. Preliminary results suggest small contributions from a low partial melt MORB mixing with a more radiogenic endmember such as a HIMU (high $^{238}U/^{204}Pb$) plume. By coupling noble gas geochemistry with traditional geochemical analyses, we can better constrain the magmatic source and deconvolve mantle-lithosphere interactions in the EVP.

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Fingerprinting Proterozoic Bedrock in Interior Wilkes Land, East Antarctica

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Wilkes Land in East Antarctica remains one of the last geological exploration frontiers on Earth. Hidden beneath kilometres of ice, its bedrock preserves a poorly-understood tectonic history that mirrors that of southern Australia and holds critical insights into past supercontinent cycles. Here, we use new and recently published Australian and Antarctic geological and geophysical data to present a novel interpretation of the age and character of crystalline basement and sedimentary cover of interior Wilkes Land. We combine new zircon U–Pb and Hf isotopic data from remote Antarctic outcrops with aeromagnetic data observations from the conjugate Australian-Antarctic margins to identify two new Antarctic Mesoproterozoic basement provinces corresponding to the continuation of the Coompana and Madura provinces of southern Australia into Wilkes Land. Using both detrital zircon U–Pb–Hf and authigenic monazite U–Th–Pb isotopic data from glacial erratic sandstone samples, we identify the presence of Neoproterozoic sedimentary rocks covering Mesoproterozoic basement. Together, these new geological insights into the ice-covered bedrock of Wilkes Land substantially improve correlations of Antarctic and Australian geological elements and provide key constraints on the tectonic architecture of this sector of the East Antarctic Shield and its role in supercontinent reconstructions.

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Pangea Rifting Shaped the East Antarctic Landscape

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East Antarctica exhibits strongly contrasting topographic relief between the Precambrian basement domains of Indo-Antarctica and Australo-Antarctica. Plate-scale geodynamic processes and long-term fluvial/glacial erosion are broadly responsible for such variable hypsometry but their relative contribution to the Phanerozoic landscape evolution remains poorly constrained. Low-temperature thermochronology studies of exposed Precambrian basement have revealed discrete episodes of heating/cooling during the Paleozoic–Mesozoic; however, the significance of these thermal events and their relationship with the vastly different topographic responses in each domain is unclear. Furthermore, reported Paleozoic–Mesozoic cooling ages imply low long-term erosion rates which are at odds with the record of sedimentation offshore. To better elucidate the Phanerozoic landscape evolution of East Antarctica, we present the first low-temperature thermochronology data from Precambrian–Early Cambrian basement in the Bunger Hills region, located close to the transition between the Indo-Antarctic and Australo-Antarctic domains. Our results confirm the overall Paleozoic–Mesozoic cooling trend of East Antarctic basement and, combined with existing thermochronological, tectonic and stratigraphic evidence, reveal widespread thermal disturbance of Precambrian crust associated with Pangea-wide Late Paleozoic–Triassic intracontinental extension. Therefore, we infer that the topographic framework of both Indo-Antarctica and Australo-Antarctica was largely established during this Late Paleozoic–Triassic extensional phase through differential uplift of sections of Precambrian basement and the formation of large intracontinental sedimentary basins. Subsequently, prolonged erosion has acted to reinforce this landscape through the preservation of basement highlands and the focusing of large-scale erosion in low-lying sedimentary basins.

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Petrological and Geophysical Characterization of Exhumed Subcontinental Mantle along the Australian-Antarctic Ocean-Continent Transition Zone

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The final lithospheric breakup of the Australian-Antarctic rift system remains controversial due to sparse geological constraints on the nature of the basement along ocean-continent transition zones. One particular location where the early rift to drift transition can be studied is along the East Antarctic margin, and more precisely at Seamount B, offshore Terre Adélie. Dredges from this large seamount reveal the ubiquitous presence of mantle rocks (peridotites and pyroxenites) and a complete lack of either crustal fragments or volcanic and plutonic rocks (basalts, gabbros), the latter being characteristic of steady-state ocean crust. We present new petrological characterization of these dredged mantle rocks and combine them with new interpretations of multichannel seismic reflection transects on either side of Seamount B. By combining both datasets, we show that a 50–100 km wide domain of cold and fertile subcontinental mantle was exhumed along this non-volcanic Antarctic margin. These mantle rocks show strikingly similar features as exhumed mantle rocks along other (ultra)-slow passive margins worldwide. In addition, they preserve characteristics similar to mantle xenoliths found in syn- to post-rift volcanism at the eastern end of the Australian margin (Victoria and Tasmania), indicating the sampling of a common fertile subcontinental mantle during rifting between Australia and Antarctica. We will further discuss the implications of Seamount B on our understanding of the rift-to drift transition and magnetic anomaly patterns along the Australian-Antarctic margin.

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3D modelling from multichannel seismic, ODP sediments and potential fields analysis of the South Orkney Microcontinent (southern Scotia Arc, Antarctica)

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The South Orkney Microcontinent (SOM) is a key element in the reconstruction of the opening and deepening of the Powell Basin, and hence the Drake Passage. The SOM is the largest continental block, with an area of more than 70.000 km2, and is located in the central sector of the South Scotia Ridge and the northern Weddell Sea. Geological and geophysical modelling enables to characterise the nature of the margins and the complex structure of the SOM that respond to different tectonic phases since the Mesozoic.

Geological records in the area include the Hole 696B from the Ocean Drilling Program (ODP) located in the south-eastern margin of the SOM. This hole span from Middle Eocene to the Quaternary in its 650 m of sedimentary record. We combine the results from sonic data obtained on shipboard at 696B with multi-channel seismic profiles that cross the hole and nearby to make an age-depth conversion. Seismic data come from the Seismic Data Library (SDLS) and Spanish cruises (i.e. SCAN97; DRAKE2018). In addition, the modelling of gravimetric satellite data and compiled magnetic data from WDMAM allows to establish the basement geometry. This study presents new insights into the 3D geometry of structural highs and sedimentary basins and the tectonic evolution of the SOM.

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What does the southern margin of the Rayner Complex tell us about the amalgamation of East Antarctica?

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The Rayner Complex in East Antarctica extends >2000 km and separates a number of regions of Archean crust, making it critically important for understanding the geological development of East Antarctica. Together with its counterpart, the Eastern Ghats Province in India, it records extremely hot, long-lived metamorphism. It is generally thought that this metamorphic system developed in a back-arc that was shortened during the during the formation of the Rodinia supercontinent. However, the position of the Rayner–Eastern Ghats terrane remains a major uncertainty in Rodinia reconstructions.

Recent work in the Fisher Terrane, a volcanic arc in the southern Rayner Complex, suggests that there is additional complexity that cannot be accounted for by simply shortening an extended back-arc system. Detrital zircon data suggests the volcaniclastic rocks in the Fisher Terrane were deposited prior to Rodinia-aged metamorphism, and the Fisher Terrane was located on the same plate as the rest of the Rayner Complex. However, the Fisher Terrane records no evidence for Rodinia-aged metamorphism, despite being surrounded by high temperature Rodinia-aged metamorphic rocks. Instead, it records a single phase of high thermal gradient metamorphism at c. 510 Ma.

The fact that the Fisher Terrane does not record the same metamorphic history as the Rayner Complex until after the amalgamation of Gondwana highlights that this part of East Antarctica is still poorly understood. Future work that integrates geophysics with new data on protolith age and isotopic character is required to understand how the Fisher Complex fits into Rodinia reconstructions.

1131

A Multiproxy provenance approach to uncovering the assembly of East Gondwana in Antarctica

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East Antarctica is a collage of Precambrian terranes that assembled along a series of Neoproterozoic—Cambrian orogens during the construction of Gondwana. The least understood of these Gondwana-forming orogens is the Kuunga orogen, which records the closure of a major ocean basin between crust of Indian (Indo-Antarctica) and Australian (Australo-Antarctica) affinity. However, the location of the key boundary separating Indo-Antarctica and Australo-Antarctica within the Kuunga orogen remains controversial because extensive ice cover in East Antarctica precludes traditional characterisation of terranes.

We integrate Pb-isotope analysis of detrital feldspar grains with U-Pb dating of detrital monazite and zircon grains from offshore sediments to infer the location of the onshore boundary between Indo-Antarctica and Australo-Antarctica. New and compiled data from onshore basement exposures highlight the distinct age and Pb-isotope signatures of Indo-Antarctica and Australo-Antarctica. Holocene sediments offshore from Mirny Station (Queen Mary Land) have detrital feldspar Pb-isotope signatures and detrital monazite and zircon ages that reflect contributions from both Indo-Antarctica and Australo-Antarctica.

The presence of both Indo-Antarctic and Australo-Antarctic crust beneath ice cover near Mirny Station implies proximity to a fundamental terrane boundary within the Kuunga orogen, which could coincide with a geophysical lineament at ~94°E (Mirny fault). The geophysical expression of this boundary extends into the subglacial interior of East Antarctica where it may have connected with one or more previously inferred Gondwana-forming sutures. This revised geometry of the Kuunga orogen provides a new framework for interpreting future geophysical surveys and understanding the timing and evolution of the assembly of East Gondwana.

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Paleomagnetism of Jurassic Dykes from dronning Maud Land, Antarctica

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Similarities between the geology of Dronning Maud Land, Antarctica, relative to southern Africa have been well established. These include comparisons made between the Archaean Craton basement rocks, the Mesoproterozoic cratonic cover sequences and related magmatism and Paleozoic sedimentary sequences and Karoo/Ferrar magmatism. This study describes and interprets paleomagnetic and 40Ar/39Ar data from Jurassic dolerite dykes in western Dronning Maud Land (DML). Orientated block samples from dolerite dykes were analysed with spinner magnetometer and MAP 215-50 Noble Gas Mass Spectrometer at the University of Johannesburg to determine paleomagnetic poles and whole-rock 40Ar/39Ar ages. The robust geochronological results suggest ages between ~188-176 Ma. Eight dykes provided a consistent paleomagnetic pole of Plat = -52.1 & Plong = 181.0, A95 = 13, N = 8. This pole infers significant displacement of Antarctica from southern Africa at the time of emplacement of the 188-176Ma dykes studied here.

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Characterization and significance of Neoproterozoic events in East Antarctica

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East Antarctic shield (EAS) preserves relicts of ~4 billion years old history. The conventional structure of EAS proposed and repeatedly updated in the last two decades, exhibits distinct Archean to Mesoproterozoic units with debatable Neoproterozoic terrains. In the last decade, sporadic reports of Neoproterozoic magmatism and metamorphism have emerged not only in East Antarctica but also in its conjugate terrains of India and Australia.
Our recent investigations of exposed coastal outcrops of Princess Elizabeth Land (PEL) as well as proximal marine sediments off-coast of Wilkes Land (WL) and PEL indicates presence of extensive Neoproterozoic terrain in EAS. Examination of granulites from PEL indicates metamorphic assemblage developed at ~500 Ma with relicts of an ~800 Ma orogeny, as estimated from chemical geochronology of texturally constrained monazite. Heavy mineral and sedimentological data from IODP and ODP drill sites suggest polymetamorphosed terrain. Chemical geochronology of texturally constrained monazites analyzed in rock fragments also provides evidence of 700-800 Ma and ~500 Ma fabric producing event. The 700-800 Ma orogeny represents a hitherto less recognized orogenic activity preserved in EAS. This work represents the first comprehensive report of a definite Neoproterozoic orogeny in the easternmost segment of WL and PEL. Its implications for the supercontinent assembly are also discussed.

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Crust and Uppermost Mantle Structure of the Davis-Casey Region, and its Tectonic Setting within East Antarctica.

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The region between Davis and Casey stations is one of the least visited regions of East Antarctica. A deployment of GPS and seismic stations at 9 locations in this region began in the 2016/17 summer season and is ongoing, pending upgrade of key sites. The geodetic observations and seismic records will be used in a medium-term monitoring initiative to inform the interaction between the solid-Earth and cryosphere in a region with high uncertainty in (for example) the satellite observations and ice sheet modelling that constrain the contribution of the overlying ice sheet to sea level rise.

In this contribution, we present the first results from the seismology component of the deployment, which enable the seismic structure of the crust and uppermost mantle to be inferred. We use recordings of earthquakes that occurred at teleseismic distances, mostly from the Tonga-Kermadec subduction zone, Papua New Guinea and Indonesia. Using the receiver function method, we infer the significant wavespeed discontinuities within the crust, the depth of the seismic Moho, and the nature of this transition in seismic wavespeed to the mantle beneath.

We interpret these results in the light of the geology and geochronology along this margin of East Antarctica and possible interpretations of the tectonic setting of the lithospheric domains in this region. We make use of airborne geophysics compilations, and a recently published study of lithospheric boundaries constrained by multivariate data, to estimate the extent to which the seismic structure determined at the individual station locations may be extrapolated inland.

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Origin of the Conrad Rise: Key to understanding the tectonic development of the southwestern Indian Ocean during Late Cretaceous

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Conrad Rise is one of the largest edifices in the southwestern Indian Ocean. A previous investigation by Borisova et al. (1996) has shown that lavas from this structure share geochemical similarities with those from the Kerguelen archipelago and Afanasy-Nikitin Rise, raising the possibility that their mantle sources host a common continental derived component. Whether or not, these structures are produced by a common hotspot activity remains a matter of debate. Within this framework, we performed six cruises at the Conrad Rise by R/V Hakuho-Maru and collected rock samples by dredging and geophysical data.

Based on our new tectonic reconstruction by geomagnetic isochron determination, at a regional scale, the Conrad and Del Cano Rises and the southern Madagascar Plateau might have formed a single plateau during Late Cretaceous now separated into three distinct entities.

Igneous rocks were recovered from Ob, Lena, and two small seamounts on the Conrad Rise by dredging during KH-10-7, KH-19-1, and KH-20-1 cruises. They occur as massive lava, porous lava, and volcanic breccia. They are mainly alkali rocks, and lesser amounts of sub-alkali rocks were recovered. Their trace element contents are similar to those from Marion and Crozet Islands and Kerguelen Plateau. However, they have distinct Sr-Nd-Pb-Hf isotope compositions with samples from Marion Islands and Kerguelen Plateau, even in their present proximity.

This suggests that detailed and precised petrological, geochemical, geochronological, and geophysical investigations and analyses are needed for revealing the tectonic development between Gondwana break-up and seafloor spreading in the Indian Ocean during Late Cretaceous.

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High-resolution global bathymetry grids for key Cretaceous and Early Cenozoic climate stages

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Ocean currents are strongly controlled by seafloor topography. Recent studies have shown that small-scale features with slopes steeper than 0.05° significantly affect subsurface eddy velocities and the vertical structure of ocean circulation patterns. Such slope gradients represent the majority of the present-day oceanic basins. Modeling past oceanographic conditions for key climate stages requires similarly detailed paleo seafloor topography grids, in order to capture ocean currents accurately, especially for ocean models with sufficient resolution (<0.1°) to resolve eddies. However, existing paleobathymetry reconstructions use either a forward modeling approach, resulting in global grids lacking detailed seafloor roughness, or a backward modeling technique based on sediment backstripping, capturing realistic slope gradients, but for a spatially restricted area. Both approaches produce insufficient boundary conditions for high-resolution global paleo models. Here, we compute high-resolution global paleobathymetry grids, with detailed focus on the Southern Ocean, for key Cretaceous and early Cenozoic climate stages. We backstrip sediments from the modern global bathymetry, allowing the preservation of present-day seafloor slope gradients. Sediment isopach data are compiled from existing seismo-stratigraphic interpretations along the Southern Ocean margins, and expanded globally using total sediment thickness information and constant sedimentation rates. We also consider the effect of mantle flow on long-wavelength topography. The resulting grids contain realistic seafloor slope gradients and continental slopes across the continent-ocean transition zones that are similar to present-day observations. Using these detailed paleobathymetry grids for high-resolution global paleo models will help to accurately reconstruct oceanographic conditions of key climate stages and their interaction with the evolving seafloor.

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Updated tectonic framework of West Antarctica and legacy of formation upon the complex convergent margin of the Gondwana supercontinent

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Results of 21st century airborne and ground-based geophysical, radar, and geology campaigns advance our understanding of the physical properties of Antarctic lithosphere, and contribute new perspectives to the long held view that independent microcontinental blocks (terranes) underpin West Antarctica (WANT). Extensive new petrogenetic, age, and thermochronology datasets help to address questions of provenance, paleotopography, and tectonic connections among WANT, East Antarctica, Zealandia and South America. This paper integrates information from the Weddell Sea sector, including its onshore mountain highlands, Marie Byrd Land (MBL) and Ross Embayment, and the Antarctic Peninsula (AP) provinces. New and legacy datasets determine the subglacial extent and lithospheric characteristics of these provinces, and reveal common elements among sectors of the complex Gondwana margin. The body of evidence points to a shared rather than disparate geotectonic evolution within the paleo-Pacific margin system. For example, all three provinces record discontinuous magmatism in the Paleozoic, giving way to Permian through Cretaceous magmatic flare-up events linked to subduction dynamics. Strong isotopic evidence shows that Jurassic supra-subduction zone decompression melting factored in to inboard Ferrar mafic magmatism and drove coeval voluminous crustal melting and silicic magmatism in the AP. The main phase of continental margin arc magmatism was synchronous in AP and MBL, achieving substantial continental growth and stabilization across WANT, up to an inboard limit newly identified along the mid-line of Ross Embayment. This tectonic boundary is marked by a dramatic contrast in magnetic characteristics and spatially coincides with the southward continuation of the Central High beneath Ross Ice Shelf.

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The Wilkes Land sector including the Aurora Basin, and its most probable subglacial geology

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With no direct observations, the subglacial geology of the Antarctic interior is unknown. However, with a growing awareness of the complex interaction between the ice sheet and the solid Earth, there is a need for well-posed estimates of properties such as crustal heat production, extent and thickness of sedimentary basins, and timing and extent of exhumation. Constraining the likely nature of the bedrock is also the key to a better understanding of the tectonic history of East Antarctica, e.g. the extent of cratonic blocks and orientation of Proterozoic orogens.

We present a probabilistic approach to describe the range of possible interpretations of the Antarctic interior with a focus on The Wilkes Land sector, including the Aurora Basin. Along the coast, we utilize geological observations and tectonic reconstructions of Gondwana. In the interior, the constraints depend more heavily on geophysical data. We use the geological and geophysical data to construct 'membership functions' that quantify the likelihood of a given property of the subglacial geology. Properties include tectonic affiliation, crustal type and crustal stabilisation age. The membership functions are defined from a range of classification and regression methods, assembled in a novel workflow using the agrid package and provided Python code. The outcome is treated as a likelihood distribution and combined with expected prior values, for each property mapped.

Our resulting outputs and interpretations, including most likely broadscale bedrock geology, are made available as maps in widely usable formats for use in the wider geoscience and interdisciplinary Antarctic research communities.

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Scratching the surface: a marine sediment provenance record from the continental slope of central Wilkes Land, East Antarctica

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The subglacial geology in Wilkes Land, East Antarctica is masked by thick ice and remains largely unexplored. Yet the underlying crustal architecture records evidence of repeated supercontinent cycles and provides the geological template for the evolution of the Antarctic Ice Sheet. Sediment eroded from under the ice is ultimately deposited in the ocean, such that marine sediment can be used to characterize proximal subglacial geology. We use detrital grain morphology, trace element geochemistry and detrital U-Pb geochronology from a kasten core to construct the first marine sediment provenance record for the continental slope of central Wilkes Land, and provide new Pb-Pb isotopic signatures from proximal coastal outcrops for comparison. A principally igneous source is revealed with dominant age populations between c. 1200-1100 Ma and c. 1600-1300 Ma, characteristic of the proximal Banzare, Nuyina and Wilkes Provinces. The detrital geochronology suggests no change in sediment provenance over the last 23.5 ka, despite major ice sheet retreat during this time. A minor c. 700-500 Ma detrital age population unknown from the central Wilkes region was likely transported westward via icebergs to the core site. These findings broadly correspond with earlier interpretations of the subglacial geology and with erosion rates at the base of the ice sheet predicted from two ice sheet models, demonstrating the value of sediment provenance studies for uncovering proximal subglacial geology and reconstructing past ice sheet configurations.

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Opening of the Tasman Gateway - revisiting the final separation between Australia and Antarctica

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Plate tectonic motions separating Australia and Antarctica during the Cenozoic opened the Tasman Gateway around the time of the Eocene-Oligocene transition. The opening of the Tasman Gateway likely played an important role in the onset of the Antarctic Circumpolar current. While there has been ongoing discussion around the evolution of the depth of the Tasman Gateway, the timing of the tectonic opening of the Tasman Gateway has been thought to be well constrained.

In early 2019, we mapped a bathymetric feature that we interpret as an extinct spreading ridge between the East and South Tasman Rise. This finding was unexpected as most models predict that the seafloor between the East and South Tasman Rise formed early in the drift phase of Zealandia's separation from Australia (from around 83 Ma to 70 Ma), although a slightly younger formation around 60 Ma and an extinct spreading ridge were proposed for this basin, but never tectonically modelled. Further, we mapped deep (~2,500 mbsl) flat-topped seamounts proximal to the extinct spreading centre. Age, and geochemical, constraints from these seamounts, combining with plate tectonic and geodynamic understanding of seafloor and seamount formation, enables us to better constrain the timing of seafloor spreading between the East and South Tasman rises. Here, we use the new data and interpretations from the seafloor and seamounts to constrain a revised reconstruction model for the South Tasman Rise during the final stages of Australia's rifting from Antarctica, with implications for the timing and evolution of the Tasman Gateway.

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Revisiting the final separation between Australia and Antarctica – a role for the Balleny Mantle Plume?

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Plate tectonic motions between Australia and Antarctica opened Tasman Gateway around the time of the Eocene-Oligocene transition. The role of mantle plume volcanism in this separation and gateway opening is under investigation. A seamount chain extending from the Lord Howe Rise to east of Tasmania and the South Tasma Rise to the Balleny Islands in Antarctica is considered to relate to volcanism from the Balleny plume from 80 Ma to 2 Ma. This seamount chain includes the Cascade Seamount on the East Tasman Plateau which has been dated with Argon geochronology techniques to 36-37 Ma and coincides temporally with the opening of the Tasman Gateway. To the north and south of the Cascade Seamount are flat topped and conical seamounts that have not yet been dated, but could constrain the role of plume volcanism and dynamic topography in modulating the timing and rates of gateway evolution in this region.

In 2019, we mapped and sampled seamounts extending from the Lord Howe Rise to east of the South Tasman Rise. Age constraints from these seamounts combined with a HIMU geochemical signature representative of the Balleny Plume (high 143Nd/144Nd, low 87Sr/86Sr and distinctive Pb isotopic ratios) will be used to validate a role for the Balleny Plume for volcanism in this region. These geochronological and geochemical data will be incorporated into plate tectonic and geodynamic models to understand the evolution of the seafloor and seamount formation during the time of gateway opening.

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Implications of East Antarctic lithospheric structure for the history and tectonics of the Antarctic Craton

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We use a newly developed Antarctic seismic model to explore lithospheric structure and its implication for the geological history of East Antarctica. Lloyd et al [2019] use adjoint seismic tomography to invert frequency-dependent traveltimes from three component earthquake waveforms for seismic structure down to 800 km beneath Antarctica and adjacent oceans.   We use this model to estimate the thickness and thermal structure of East Antarctic continental lithosphere. Lithospheric thickness is highly variable, ranging from around 100 km to greater than 220 km. The thickest lithosphere, found in Southern Victoria Land west of the Transantarctic Mountains, probably represents the continuation of the Australian Gawler Craton and the Antarctic Terre Adélie craton beneath the ice sheet. This large region, often termed the Mawson Craton, formed the Archean to Paleoproterozoic core of Gondwana. Although much of East Antarctica has lithospheric thickness of nearly 200 km, greater variability in lithospheric thickness and structure is found beneath the East Antarctic Highlands, stretching from western Dronning Maud Land to the Lambert Graben. The uppermost mantle beneath Fimbulheimen in Dronning Maude Land is characterized by an absence of fast lithosphere, consistent with early or mid-Phanerozoic tectonic activity and lithospheric delamination. Much thinner lithosphere is also imaged beneath Enderby and Kemp Land (including the Lambert Graben), suggesting the lithosphere was disrupted and thinned due to rifting activity connected with the breakup of Gondwana and the formation of Lambert Graben.

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Antarctic subglacial geology from detrital provenance in marine sediments; examples from the Wilkes Subglacial Basin and the Weddell Sea embayment

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Thermochronologic and geochronologic ages and isotope geochemistry of glacial sediment provide a way to investigate the geology of ice-covered areas of Antarctica, particularly the parts of the hinterland that are eroding fastest.

At IODP Site U1356, offshore of the Wilkes Subglacial Basin, ice-rafted detritus (IRD) was deposited in high concentrations during the mid-Miocene climate transition. At this time the ice sheet was eroding inland areas of the basin, in contrast to today, when detritus mainly comes from the marginal areas. The dominant $^{40}Ar/^{39}Ar$ thermochronological age of the ice-rafted hornblende grains is 1400-1550 Ma, implying an inland source area of this age extending along the eastern part of the Adélie Craton, which forms the western side of the Wilkes Subglacial Basin.

In the Weddell Sea, subglacial till and proximal glaciomarine sediment from Polarstern core sites along the edge of the Filchner and Ronne Ice Shelves were used to characterize the upstream geology by projecting provenance back along ice flow lines into the embayment. Detrital hornblende and biotite $^{40}Ar/^{39}Ar$ thermochronologic and zircon U-Pb geochronologic ages reflect Cretaceous and Jurassic tectonic activity and the Ross and Grenvillian orogenies, largely corresponding to the known ages of tectonic blocks in the embayment. εNd values of the fine-grained sediment fraction are quite unradiogenic across the central and eastern side of ice-shelf front (εNd -10 to -16), compared to the western side. We infer that the central sediments may be derived from Beacon-age sedimentary rocks, themselves derived from East Antarctica.

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SESSION 14

INTEGRATING MARINE AND TERRESTRIAL RECORDS OF PAST ANTARCTIC ICE SHEET AND OCEAN BEHAVIOUR

Mike Bentley

Julia Wellner, Richard Jones, Christina Riesselman

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Preliminary analysis of abandoned Holocene penguin rookeries at South Shetland Islands, Antarctica

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Penguins are climatic sensitive seabirds that establish colonies along the marine coasts of Antarctica since the Paleocene (60 million of years ago) to which they return every year during the breeding season. Accumulations of bones, pebbles, and guano constitute rookeries, that condense and transform into ornithogenic soils preserving evidence of nesting constitution, penguins diet, and biological interactions in the past. We prospected the 25 de Mayo/King George Island (South Shetland Islands) looking for the reported rookeries in the Potter Peninsula (Pingüi could not be re-located following the published coordinates). Pingfo II corresponds to raised marine deposits with bones dated in 7780 ± 60 yr BP and 7600 ± 80 yr BP without modern colonies at the top. Ornithogenic soils were not detected, and the disarticulation and weathering of bones indicate transport and accumulation in a high energy beach. Pingfo I is a more elevated recolonized area within ZAEP 132 with hundreds of Pygoscelis adeliae at the top since 2012 (monitoring program Instituto Antártico Argentino). Seven levels yield bones dated in 5750 ± 40 yr BP and 5840 ± 40 yr BP. The abundance of bones of different ontogenetic stages, the presence of eggshells, seaweeds, and pebbles, and the lack of evidence of transportation suggest that the breeding colony was settled in this area. We continue with the sieved sediment and consolidated blocks rich in organic material processing in the lab, in the search for traces of penguins diet, and small organisms that could offer paleoclimatic, paleoecological, and pedological information.

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A probabilistic and model-based approach to the assessment of ice sheet change from glacial detritus.

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Detrital provenance methods are used to understand changing ice sheet conditions, often seeking to characterise eroding zones that may indicate the past location of the ice sheet margin, but interpretation is often ambiguous. We present a probabilistic approach to map the generation of detritus. First, a subglacial geology map is made from geophysical data, in which we estimate likelihoods for basement geology and cover sequence classes to be exposed at the base of the ice sheet. Second, using ice sheet models, erosion likelihood is estimated for four different ice sheet states. Third, spatial analysis is applied to determine the likelihood of erosion for each geological class in each ice sheet state. These likelihood estimates help to validate and constrain interpretations of detrital records. By also considering prior probabilities, our formulation allows a further qualitative interpretation mode in which indicator and contra-indicator classes are defined for each ice sheet model, allowing the support for different ice sheet states to be compared. Finally, given a relative prior probability for the ice sheet state and a transport effectiveness, the relative probability of different ice sheet states may be calculated quantitatively. An application in Wilkes Land demonstrates that observed detritus in recent strata is consistent with derivation from the modern-scale ice sheet model, and demonstrates the capacity to quantitatively discriminate the different ice sheet states from detrital occurences. Our new approaches support a more robust capacity interpret ice sheet change from the detrital record in both qualitative and quantitative ways.

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Antarctic impact on ocean circulation during late Messinian ocean circulation, insights from IODP Exp. 361 sites.

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Different models indicate a marked increase in ice-volume in Antarctica (approx. 50%) during the late Messinian, that culminate in large glaciations (TG22, 20 and 18) when the Antarctic ice-sheet was probably larger than today. Until recently there were only limited late Messinian records that could be used to investigate the influence of these Antarctic ice-sheet expansions on paleoclimatic and palaeoceanographic variability. A key location where this influence is poorly known is the boundary between the Indian and the Atlantic Ocean, which is an integral inter-ocean link in the global thermohaline circulation. In 2016 the International Ocean Discovery Program (IODP) Expedition 361 ("SAFARI") recovered a complete high-resolution Messinian sedimentary succession at 3 drilling locations on the southeast African margin and in the Indian-Atlantic Ocean gateway. Here we present results from Site U1475 (Agulhas Plateau), a location proximal to the entrance of North Atlantic Deep Water (NADW) to the Southern Ocean and South Indian Ocean. The site is located over sedimentary drift deposits in 2669 m water depth and comprised of carbonate-rich sediments (74 – 85 wt % $CaCO_3$). Based on high-resolution data sets of density, velocity, natural gamma radiation, X-ray fluorescence (XRF) core-scanning data, colour reflectance, grain size distributions and planktonic foraminifera oxygen isotope data, we reconstruct major circulation changes in bottom current as well variations in orbitally-controlled climate variability that can be linked to the Antarctic ice-sheet expansions.

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High-resolution paleolimnological records from Larsemann Hills, East Antarctica over the last two millenia

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High-resolution sediment records from Antarctica are rare due to the depositional rates and conditions that prevail in this cold continent. The sedimentary records from the ice-free regions of Antarctica form important links between the ice-core and the marine sedimentary records. Recently, significant number of past-climate records from East Antarctic lacustrine sediments has exhibited the evolution of the lake ecosystem and the Antarctic climate. The resolution of the sedimentary records is generally coarse varying between 200 to 600 years owing to the slow depositional rates and conditions. High-resolution Holocene records are important to understand the response of lakes to the recent climate. Here, we present high-resolution sedimentary records from two coastal lakes viz., Discussion Lake and Mochou Lake located in Larsemann Hills of East Antarctica. . The radiocarbon dates sedimentary records span the last 2,000 years. The former is at an elevation of 5 m asl while the latter is at 10 m. We have generated multi-proxy sedimentary organic chemistry data ($\delta13C$,$\delta15N$, Corg content, Nitrogen content) along with diatom abundance to understand the impact of climate on the lake ecosystem. We compared our data with the recently reconstructed PAGES2K global climate data in order to find any distinct climate events within the last two millennia. Though a one-to-one correlation doesn't exist, distinct similarities can be drawn from the two data sets. At the outset, though the records mimic the global climate records (PAGES2K), there exists certain lag due to the high-resolution ice-core records and relatively low-resolution of the lacustrine sedimentary records.

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A morpho-stratigraphic reconstruction of Edisto Inlet and Mc Robertson Bay based on high-resolution Holocene paleoclimate record, western Ross Sea (Antarctica)

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A high-resolution seismic-bathymetric survey was conducted in western Victoria Land in two fjords: Edisto Inlet (Cape Hallett) and Mc Robertson Bay (Cape Adare). Observed changes in the geometry and sedimentation patterns from late-glacial to present reflect the interactions between the dynamical fluctuations of local outlet glaciers systems and oceanic circulation. Both are key sites to investigate recent past polar amplification due to the late deglaciation climate warming. Edisto Inlet and Robertson Bay are, indeed, located along the route of main ocean bottom water masses forming into the Ross Sea continental shelf and of intermediate waters intruding from the open-ocean.

The data collected in 2005, 2017 PNRA and in 2015 KOPRI surveys, document peculiar environmental and ocean circulation conditions that have probably persisted for several thousand years, after the retreat of coastal glaciers since the last glacial maximum (21 ka). The sediments analysis suggests high paleo-productivity in the water column and the presence of bottom currents with relatively constant direction and intensity over time.

Here we present results of a preliminary integrated analysis of all geophysical and geological dataset aimed to understand relationship between the geometry and the spatial distribution of depositional and erosional features. Conclusions of this work are critical to reconstruct ice-sheet and bottom currents past history and to better constrain ice-sheet and ocean numerical simulations of the Holocene.

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Glacial history of the South Orkney Islands shelf (NW Weddell Sea): insights from new bathymetric and multi-channel seismic data

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The South Orkney Islands (SOI) are partially covered by modern ice caps. The SOI shelf was shaped during repeated ice sheet advances and retreats, as evidenced by presence of ice-rafted debris in the ODP Leg 113 (1987) sections since late Pliocene. Glacial geomorphological features of the SOI shelf include several erosional troughs and a continuous mid-shelf break, which marks the maximum extent of ice grounding at ~350m isobath (e.g. Dickens et al., 2014). In 2018 (63rd Russian Antarctic Expedition), ca. 500 km of new multibeam and multi-channel seismic (MCS) data were collected on the SOI shelf by the RV “Akademik Karpinsky”. During the cruise, a detailed multibeam survey was performed across the Signy glacial trough. As a result, a 30m resolution bathymetric grid was compiled for the area of ca. 1500 km2, which allows to describe the trough morphology in greater detail, and to identify grounding-zone moraines on the flanks of the trough. Detailed reprocessing of the MCS data was performed to better resolve the upper part of the seismic record. Interpretation of time sections was improved with the help of multibeam depth profiles collected along the seismic lines. This allowed to distinguish erosional troughs and well-developed grounding zone moraines in the MCS sections. The mid-shelf break position at ~350m isobath is well recognized in the 2018 multibeam and MCS data. Additionally, we propose a more distal position of grounding ice at ca. 400m water depth.
This study is supported by the Russian Foundation for Basic Research (project no. 19-05-00858).

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Glacial history of the Coats Land region, East Antarctica

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Satellite gravimetry is a widely-used technique of assessing ice sheet mass change. For its application it requires a correction for glacio-isostatic adjustment, which can be of an order of magnitude comparable to that of the 'raw' gravimetric signal. In order to improve these GIA corrections one powerful approach is to reduce uncertainties in the two main inputs: (i) the ice load history and (ii) the understanding of solid Earth structure in the loaded region. For the Antarctic ice sheet the largest differences between modelled GIA corrections occurs in Coats Land, that part of the East Antarctic Ice Sheet that drains into the north-eastern Weddell Sea Embayment. Here we report a multi-disciplinary study to improve our understanding of ice load and Earth structure in this region. We report here on a programme of glacial geology, GPS and seismometer deployment, and modelling; all aimed at improving GIA corrections and thus reducing the uncertainties in ice sheet mass balance in a key region.
We have mapped and sampled the glacial geological record of ice sheet fluctuations on a transect of nunatak sites stretching ~900 km from the Heimefrontfjella (74° 30'S) to the Whichaway nunataks (81° 30'). The glacial geomorphology is a consistent pattern of landforms and glacial deposits, which record a glacial (ice loading) history of the region that we have dated using two independent approaches of comsogenic Be-10 surface exposure dating and by radiocarbon dating of mumiyo (preserved stratigraphic deposits of proventricular stomach oil from snow petrels, Pagodroma nivea). We have deployed GPS receivers in a network to record contemporary surface motion, and at some sites have installed co-located seismometers to provide data for tomographic reconstructions of Earth structure. The glacial history provides constraints for our ice sheet modelling. Once we have preferred data-constrained simulations of ice sheet (load) history then we aim to run GIA models to provide updated GIA corrections for improved satellite gravimetry measurements of this region.

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Late Pleistocene environmental conditions in East Antarctica - evidence from snow petrel stomach oil deposits ("mumiyo")

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Sub-fossil stomach oil of snow petrels (Pagodroma nivea) forms unique deposits of so-called mumiyo in the vicinity of the bird's nests in ice-free areas of Antarctica. The deposits are indicators for un-glaciated terrestrial sites but also provide records of the occupation histories of the inland breeding localities by snow petrels as well as for productive foraging areas off the coast. Previous studies showed that mumiyo deposits can contain intact stratigraphy making them suitable for nearly continuous paleo-studies ranging back for more than 55 thousand years.
Due to the dominantly marine origin of the organic material in mumiyo deposits, they form an archive that integrates marine and terrestrial information of past environmental conditions. We suggest that changes in the oceanic foraging habitat of the snow petrels (e.g. with respect to nutrient availability, sea ice conditions, biogeochemical cycling) are represented in the composition of snow petrel stomach oil and finally in mumiyo deposits. In order to derive proxies for paleoceanographic and -climatic reconstructions from mumiyo deposits, we analyse lipid biomarkers (mainly fatty acids and alcohols) and stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) on mumiyo from different regions in East Antarctica and covering a wide range of ages (fresh stomach oil, and sub-fossil material of up to 55 thousand years old). This allows for identifying spatio-temporal variations in composition and possible effects of post-depositional alteration.

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The use of meteoric 10Be from sub-ice shelf sediments as a proxy for the Holocene retreat and sub-shelf dynamics of the Amery Ice Shelf, post LGM

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Ice shelves are critical in ‘buttressing’ grounded ice by providing lateral back stress to ice streams and stabilising the mass balance of an ice sheet. They are susceptible to mass loss, leading to dynamic thinning and once removed, acceleration of grounded ice sheets. This is particularly important where ice sheets are grounded below sea level and prone to Marine Ice Sheet Instability, as is much of the East Antarctic Ice Sheet.

Sub-ice shelf environments are one of the few places where it is possible to observe past ice retreat inland of current ice sheet boundaries. Recently, meteoric ^{10}Be has been used to distinguish successfully between sub-glacial, sub-ice shelf and marine environments from core top samples below the Ross Ice Shelf and the Ross Sea.

This study aims to assess the viability of meteoric ^{10}Be as a proxy for paleo sub-ice shelf dynamics under the Amery Ice Shelf (AIS), during the Holocene. We sampled down four sub-ice shelf cores to observe whether the calving front retreated upstream from its present extent during a warm period from ~11.5-9.5 ka, when average global atmospheric temperatures were ~1°C higher than present.

Results indicate the AIS margin didn’t retreat significantly beyond its present extent during the Holocene, suggesting the threshold for ice shelf destabilization lies between Holocene (+1°C) and Pliocene (+3-4°C) conditions. Furthermore, the concentration of ^{10}Be was successfully used to track the movement and intensity of sub-shelf currents, which in the Amery system have remained relatively consistent since ~ 5 ka BP.

Central Scotia Sea bathymetry compilation and geological map international initiative (BATCESSEA)

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This new bathymetry compilation of the Central Scotia Sea (CSS) represents an international initiative coordinated by IGME (Spain), BAS (UK) and AWI (Germany) incorporating additional data from other partners. The planned bathymetrical and geological map will cover an area of 1492300 km2 between parallels 52ºS and 64ºS and between meridians 50ºW and 31ºW. In this area, the existing high resolution bathymetric data cover at least the 50% of the region with a 100 to 200 m cell resolution for the sea floor topography. This information was collected over the last 30 years on dozens of cruises onboard different Antarctic research vessels. The CSS is the natural prolongation to the east of the Drake Passage gateway, which connects the southeastern Pacific and the southwestern Atlantic oceans, interacting additionally with the Weddell Sea. Geological and oceanographic processes in this area influence mantle flow, oceanographic water mass exchanges and migrations of biota. The geodynamic evolution, seismic activity and tectonic data suggest a complex evolution where important continental fragmentation and oceanic spreading processes have configured a puzzle of sedimentary basins and submerged continental banks, as South Orkney, South Georgia and Discovery among others, permitting the present pattern of global ocean circulation to be established. This initiative is part of the IBCSO, an SCAR Expert Group, which recognizes the importance of regional compilations in areas of scientific interest in Antarctica. This map will enhance the BAS GEOMAP 2 Series products about the Scotia Arc, after the published Drake and South Sandwich maps and bathymetric compilations.

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Glacial/interglacial history of environmental and oceanographic change on the Adelie Land/Wilkes Land Margin, East Antarctica

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Geomorphological and sedimentological evidence is used to interpret the glacial/interglacial history over the last ~250 ka of the Adelie/Wilkes Land region comprising changes in productivity, ice sheet expansion, and oceanic circulation including the formation of Adelie Land Antarctic Bottom Water (ALBW). The slope and rise of the continental margin are currently made up of a series of large submarine channels. These channels are currently inactive and infilling, with the exception of the Jussieu Channel which is an active conduit for ALBW. Sediment cores from ridges between the submarine channels preserve two dominant modes of sedimentation. The first is interglacial hemipelagic deposition of massive, highly bioturbated silts with evidence for biological productivity and ice rafted debris (IRD), with some evidence for contourites. The second mode of sedimentation is glacial hyperpycnites and turbidites. These contain minimal biological productivity, varying bioturbation and negligible IRD. The hyperpycnites are interpreted to be sourced from turbid sediment-laden plumes of meltwater from beneath the East Antarctic ice sheet during the glacials, with ice streams extending to the edge of the continental shelf and may have formed large submarine channels on the continental slope during the glacials. There is some variation in sedimentation between the different glacials, which likely reflects the extent of the ice sheet across the shelf, and the presence or absence of sills on the shelf edge.

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Biogenic silica production and burial in the Ross Sea: A potential link between nutrient supply and CO2 drawdown during Miocene Climatic Optimum

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The Miocene Climate Optimum (MCO ~17-14.5 Ma) was the warmest climate interval of the last ~35 Ma and immediately preceded the Middle Miocene Climate Transition (MMCT; ~14 Ma), a major interval of Antarctic ice expansion and global cooling. Marine sediment records indicate that the MCO was associated with global-scale changes in carbon cycling possibly reflecting increased silicate weathering in Antarctica due to the orbitally-paced development of a temperate ice sheet. Yet there are relatively few records from ice proximal regions that constrain the dynamic ocean-ice sheet feedbacks; the response of the Antarctic ice sheets to warming during the MCO has the potential to provide insight for future warming scenarios.
IODP Expedition 374 to the Ross Sea recovered a well-preserved early to middle Miocene diatom-bearing/-rich mudstone to diatomite sequence (Unit III) from continental shelf Site U1521. High biogenic opal concentrations (30-55%) in Unit III (85.34-209.17m CSF-A) represent a period of predominately open marine conditions from ~16.7 and 15.8 Ma (preliminary shipboard age model). However, high-magnitude fluctuations in biogenic opal concentration suggest variable marine primary productivity over the MCO, likely reflecting a dynamic ice sheet. Our working hypothesis is that high biogenic opal concentrations represent periods of increased nutrient supply, possibly as a result of enhanced terrestrial silicate weathering associated with Antarctic glacial advance/retreat. The subsequent burial of large amounts of biogenic opal, as well as the corresponding organic carbon, could serve as a major global carbon sink, and highlights the potential role of Antarctic silicate weathering in controlling atmospheric CO2 levels.

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PALEOSTRIP: a backstripping MATLAB© code applied to marine continental margins

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We present PALEOSTRIP, an open-source code developed for MATLAB© to perform 3D-backstripping of marine continental margins sediment body. Backstripping consists in decompaction of sediment layers through time. During decompaction, flexural or local isostatic correction can be applied. PALEOSTRIP also includes a module of post-rift thermal subsidence based on the McKenzie rifting model. Finally, paleo eustatic sea-level corrections can be applied to the backstripped sediment layers, following well-known eustatic sea level curves, or following user-prescribed 1D or 2D sea level corrections. Most of PALEOSTRIP parameters can be prescribed homogeneously or be spatially variable over the grid domain. The different set of corrections, including thermal subsidence, can be activated or deactivated, allowing for a full parametric study of backstripping uncertainty. PALEOSTRIP allows to backstrip wells (1D), 2D transects or 3D maps.

Here we apply the code to paleobathymetric reconstructions of the Ross Sea (Antarctica) from the Late Oligocene (25 Ma) to the Plio-Pleistocene. Compared to the pan-Antarctic reconstructions, in which geophysical parameters are usually homogeneous over the entire domain, the regional backstripping approach allows more refined reconstructions of the paleobathymetry. A set of tuned geophysical parameters is constrained by existing deep drilling sites, such as IODP leg 28 and IODP leg 374. Reconstructions are embedded in the recent pan-Antarctic reconstructions from Paxman et al. (2019). We use those reconstructions to force an ice sheet model and show the difference between backstripped pan-Antarctic or regional reconstructions.

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The Odyssea Contourite Depositional System (Ross Sea): a combined record of ice sheet and ocean activity.

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Contourite Depositional Systems are produced in areas where bottom currents play a dominant role in mobilizing sediment and therefore represent a precious continuous record of oceanic currents activity and sediment availability, both related to ice sheet advances/retreats in polar areas. This study focuses on the Odyssea Contourite Depositional System, located between the Iselin Bank and the Hillary Canyon. This area lies under the effect of the Antarctic Slope Current, flowing along the continental slope and carrying relatively warm waters, and of the cascading dense water masses that are produced on the continental shelf. The Hillary Canyon represents the main conduit for dense waters and sediments flowing down-slope but also a preferential pathway for the relatively warm waters to reach the continental shelf. During maximum glacial advances, when the Antarctic ice sheet had its grounding line close to the shelf edge, the intrusion of warm waters from the Hillary Canyon could have produced basal melting and affected the stability of the ice sheet.

The interpretation of the seismic lines acquired within the PNRA-ODYSSEA project by the research vessel OGS Explora in 2017 across the southeastern flank of the Iselin Bank allows to study the stratigraphic record of the Odyssea Contourite Depositional System. New data acquired in 2018 by IODP Expedition 374 will help in the reconstruction of the processes acting in the area since the late Miocene. In turn, the hypothesis coming out from the interpretation of wells and seismic data can be tested by numerical models.

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Fe-Si-oxyhydroxide deposits at Hook Ridge of Bransfield Strait, Antarctica

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Geological and geophysical investigations were carried out in Hook Ridge of Bransfield strait, Antarctica, during the R/V Xianghong No.1 cruise in 2017/2018. The seafloor hydrothermal fields was discovered which will help us to understand the fundamental processes controlling the exchange of material and energy between different spheres of the earth. In Hook Ridge, the Fe- and Si-rich oxyhydroxide deposits were recovered using the TV-grab. They mainly occur as the chimney at the seafloor associated with the fragments. There are no crystalline minerals in these deposits because of no identifiable peaks on the XRD patterns. The whole rock composition of these deposits is dominated by high Fe and Si contents. The contents of V, Ge, Sr, Mo and Ba are also relatively high in samples, while other trace elements concentrations are low(Cu+Co+Ni+Zn<30.32 wt%). The total rare earth element contents are low (41.847-47.077 ppm), and the chondrite-normalized distribution patterns show the notable negative Eu and Y anomalies. Sr isotopic compositions are slightly lower than those of seawater. Nd isotopic compositions of samples varies from εNd=+5.9 to +6.9, possible recording the mixing between seawater and basement rock. Pb isotopic compositions are closed to the Atlantic sediments. All these facts refer to the hydrothermal origin, with the minor contribution of biogenic processes.

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Miocene Initiation of the Complete Antarctic Circumpolar Current:
A Causal Link to Late Miocene Climate Cooling?

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Initiation of a complete Antarctic Circumpolar Current (ACC) has been regarded as dependent on the opening of deep seaways south of Tasmania and South America. The late Eocene to early Oligocene age of these tectonic events has led to the suggestion of a causal link to Antarctic glaciation through the thermal isolation of the continent by the current. The timing of the first oceanic lithosphere in Drake Passage between South America and the Antarctic Peninsula is well established at ca. 30 Ma. However, geochronologic and geochemical study of rocks dredged in the central Scotia Sea has led to the hypothesis that an 'ancestral South Sandwich arc' (ASSA) could have formed a barrier to easterly throughflow of deep water from this gateway even as it opened (Pearce et al., 2014). Recent seismic tomography resulting from the United States Antarctic component of the international Polar Observing Network (POLENET) project has now provided independent evidence for the existence of the ASSA by imaging of an anomalously fast region in the mantle transition zone beneath the west-central Scotia Sea. The ASSA is comparable to the active South Sandwich arc to the east where subduction of the South American plate is imaged (Lloyd et al., 2019). Might the mid-late Miocene removal of this final barrier to a complete ACC be causally linked to the intensification of global cooling and formation of a cold-based Antarctic ice sheet?
Lloyd, A., et al., International Symposium Antarctic Earth Sciences, 2019
Pearce, J., et al., Global and Planetary Change, 2014

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Miocene paleobathymetric reconstruction of the Ross Sea (Antarctica)

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Today the continental shelf of the Ross Sea is overdeepened (average 500 m at the shelf edge), and landward deepening, as the result of erosion by multiple ice sheet advances over the seabed and deposition of morainal banks at the continental shelf edge. In fast-flowing areas, the amount and rate of the erosion at the ice sheet base depends on the thickness of the ice, the ice velocity, the occurrence of basal meltwater, the nature of the bed, the duration of ice sheet advance, etc. At the grounding line, the water-saturated sediments entrained at the base is released and deposited on the seabed.

Since the onset of Antarctic glaciations, erosion of the continental shelf and sediment deposition at the continental margin gradually shaped the Ross Sea bed through time. Reconstructing the evolution of the sea bed morphology and depth can therefore help inferring ice sheet extent and flow regime, and represents boundary conditions to numerical simulations of past ice sheet dynamics.

We present the preliminary results of backstripping modelling applied to the Ross Sea. Depth converted maps of some principal Miocene unconformities, based on the entire set of international seismic data, are used to reconstruct the Ross Sea paleobathymetry changes around the Miocene. Reconstructed paleodepths show a gradual deepening and seaward widening of the Ross Sea. The depth maps have been restored after removing sediment load, assuming isostatic compensation, post-rift thermal subsidence and accounting for geological constraints from DSDP leg 28 and IODP Exp. 374 sites.

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Vegetation and environments during early history of the East Antarctic ice sheet: High-resolution palynological insights from Sabrina Coast, East Antarctica

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The Aurora Subglacial Basin contains an estimated 3.5 m of global sea level equivalent ice and is primarily drained by the Totten Glacier system, which terminates at the Sabrina Coast, East Antarctica. Thinning of the Totten Glacier indicates this region is highly susceptible to oceanographic and atmospheric changes. A paleoclimate perspective on these changes will improve understanding of East Antarctic Ice Sheet (EAIS) dynamics in this sensitive system. Here we present high-resolution palynological data from NBP 14-02 jumbo piston cores (JPC) JPC-54 and JPC-55, which enable reconstruction of regional environments during EAIS development. The Sabrina Flora is dominated by angiosperms, with Gambierina spp., often exceeding 40% of the assemblage. Diverse Proteaceae, Battenipollis spp., Nothofagidites spp., and conifer palynomorphs are also notable. Pristine preservation and the frequent occurrence of Gambierina spp. clusters indicate the majority of the Sabrina Flora assemblage is deposited penecontemporaneous with sedimentation. Biostratigraphic results indicate JPC-55 and JPC-54 as latest Paleocene and early-mid Eocene sediments, respectively. Biomarker evidence of plant wax n-alkanoic acid yields average $\delta^{13}C_{30}$ values of -30.2±0.5‰ (JPC-54 only) consistent with open canopy woodland or shrubby tundra. δD_{30} values were stable across JPC-54 and 55 with a mean -215±4.5‰. A fractionation of ~-100‰ indicates δDprecip of -128‰, slightly more positive than coastal snow in the same region today, suggesting sourcing of plant biomarkers from close to the coast. Integration of biomarker and palynological results are consistent with a drier, more open type of coastal vegetation rather than the closed rainforest vegetation often envisaged for Paleocene-Eocene Antarctica.

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Diatom paleoproductivity as impacted by evolving cold-climate conditions during the Pliocene-Pleistocene transition along Wilkes Land, East Antarctica

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Marine-based glaciers fronting the East Antarctic are vulnerable to warming sea-temperatures. During the Mid-Pliocene Warm Period (MPWP), an analog for current global warming, the retreat of the East Antarctic Ice Sheet into the Wilkes Subglacial Basin contributed 3-10 meters of sea-level rise (Cook et al., 2013). A few degrees cooler or warmer than pre-industrial temperatures dictate the presence of large ice sheets, the strength and position of global circulation patterns, and the survival of ecosystems. The diatom assemblage from IODP site U1361, located on the Wilkes Land Margin continental rise, demonstrates the changes in the Southern Ocean environment that occurred when the Earth cooled by 2-3°C following the MPWP. Shifts in the assemblage link to the intensification of global glaciation between 2.4-2.73 Ma, the stabilization of EAIS, and rearrangement of circulation features. Diatoms are a dominant Southern Ocean phytoplankton whose silica-structure is well preserved in sediments. The environmental preferences of specific species are derived from modern studies that characterize the distribution of extant taxa in the Southern Ocean. The biogenic silica content of the bulk sediment (BSi) correlates to primary productivity in the photic zone and/or the influx of terrigenous material. High BSi (> 15 wt%) corresponds to interglacials and shifts in the periodicity of BSi, i.e. the frequency and duration of primary productivity, occur concurrently with major environmental shifts.

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The response of Antarctic vegetation to Oligocene and Neogene climate variability

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Over the course of the Cenozoic, Antarctic vegetation has transformed from temperate and near-tropical forests, to a very sparse macroflora inhabiting the ice-covered continent of today. The timing of the demise of vegetation in Antarctica has been long debated and is inferred to have occurred in response to climate cooling during the late Miocene or Pliocene. Here we use plant wax abundances, distributions and compound specific isotopes ($\delta^{13}C$ and $\delta^{2}H$) from onshore and proximal marine Antarctic outcrops and drill cores to investigate how Antarctic vegetation responded to, and survived, climate variability in the Oligocene and Neogene. Plant wax isotopic trends are sensitive to an array of environmental forcings, including water availability, temperature and seasonality. In particular we focus on three key climate transitions; the extensive Mi-1 glaciation at the Oligocene/Miocene boundary (23 Ma) which marks a key step in Cenozoic Antarctic ice sheet history from relative warmth in the late Oligocene to large temperature and ice volume fluctuations in early Miocene, the Miocene Climate Optimum (17-15 Ma) when atmospheric CO_2 and temperatures were at levels similar to those projected for the coming century, and the Miocene Climate Transition (14-13 Ma) where ice in Antarctica increased, temperature cooled and CO_2 levels dropped.

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The modern circum-Antarctic distribution of biogenic opal accumulation and lessons for paleoceanography

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The Southern Ocean has been identified to represent a major sink of biogenic-bound silicon (BSi) and to play a key role in controlling the global ocean silica cycle. The major deposition of biogenic opal ($BSiO_2$) in the Southern Ocean occurs in a near-circumantarctic band, the so-called "Antarctic opal belt", roughly bounded by the winter sea ice edge to its South and the Subantarctic Front to its North. Major contributors to the $BSiO_2$ deposition are siliceous hardparts of diatoms. Here we present new $BSiO_2$ concentration data and ^{230}Th-normalized flux data to enhance the data coverage in the Southern Ocean. This allows for the generation of a circum-Antarctic map of biogenic opal deposition from more than 1250 sites. As such, we improve the knowledge on the $BSiO_2$ deposition pattern in the Southern Ocean and augment the robustness of estimates concerning modern BSi flux rates, which is substantial for the understanding of silica cycling in the world ocean. With this we address the ongoing debate whether the Southern Ocean represents a major exporter of Si or it only imports Si to compensate for the BSi burial in the sediments. Another goal of our study is the improvement of the baselines needed to apply Southern Ocean $BSiO_2$ deposition as a proxy for paleoceanographic reconstruction. This requires understanding of the physical and biological processes governing the production, accumulation and distribution pattern of $BSiO_2$, together with the paleoceanographic significance of the related distribution pattern of main diatom species building the majority the Southern Ocean $BSiO_2$ deposition.

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Establishment of the modern Antarctic Circumpolar Current

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Key words: Neodymium isotopes, Sortable silt, Circumpolar Deep Water, Antarctic Circumpolar Current

The Antarctic Circumpolar Current (ACC) plays today a key role in the global ocean, the Antarctic ice sheet and thereby the global climate system. The timing of the onset of the strong, deep-reaching ACC flow remains controversial, representing a fundamental gap in our understanding in the evolution of the global ocean circulation, and its role on the paleoclimate. Here, we present coupled records of neodymium isotope ratios (εNd) generated from fossil fish teeth/bone debris, biogenic silica and mean grain size of sortable silt from pelagic sediments recovered from the Deep Sea Drilling Project Site 278 on the South Emerald Basin. Our data provide critical insights on the establishment of the modern-like strong, deep-reaching ACC through changes in the evolution of the Circumpolar Deep Water on the Pacific side of the Tasmanian Gateway, from the middle Oligocene to the Pleistocene (~31-1 Ma). Around the Pliocene-Pleistocene transition, the εNd values at Site 278 converge with the values of the present-day Circumpolar Deep Water. This is nearly coeval with a major step-like increase in the mean grain size of sortable silt and biogenic silica records suggesting a causal relationship between the development of the modern-like homogenous Circumpolar Deep Water εNd values in the Southern Ocean and the establishment of the strong, deep-reaching ACC.

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Submarine canyons off Cape Darnley, East Antarctica

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The Antarctica continental slope off Cape Darnley is known as a major pathway of colder, less saline, and denser bottom water, which is produced in the Cape Darnley polynya and known as the Cape Darnley Bottom Water (CDBW). The mooring observations showed that significant signals of the CDBW occurs at the center of the Wild Canyon (Ohshima et al., 2013). Intensive erosion and material transports from shallow regions to deep ocean can be expected here, but the relationship between bottom water and submarine canyons is still debated. Here we present new observations from large networks of submarine canyons off Cape Darnley. We conducted underway geophysical mapping, multichannel reflection seismic survey, bottom rock and sediment sampling during the R/V Hakuho-maru KH-19-1 and KH-20-1 cruises. Multibeam bathymetry, sub-bottom profiler, total and vector magnetic fields, and gravity data were acquired along ship tracks. New bathymetric map reveals that a large channel network of submarine canyons exists in the pathway of known CDBW area. Sub-bottom and multichannel seismic reflection profile show sub-seafloor structure of submarine canyons and surrounding sedimentary layers. Based on collected rocks, sediments, and deep-sea camera observations, it is shown that seafloor surface is covered with angular clast and sand in the shallower part of the channel. Furthermore, sandy silt with current ripple morphology is deposited in the deeper part of the channel. These results imply that a main stream of the CDBW may contribute to erosion, transportation, and sedimentation at the submarine canyons, shaping the seafloor off Cape Darnley continental slope.

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Geo-paleontological re-significance of the Cockburn Island (James Ross Basin, West Antarctica)

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Cockburn Island is located in the northwest of the Weddell Sea between Marambio/Seymour and James Ross islands, less than a hundred kilometres from the Antarctic Peninsula. The stratigraphic units recognized were already correlated with the known sequence of the James Ross Basin, including the Snow Hill Island Formation (Cretaceous), the lower allomembers of La Meseta Formation (Paleocene-Eocene), and Neogene rocks unconformable lying at the top. The upper plateau is formed by a Miocene–Pliocene flat level of volcanic rocks of the James Ross Island Volcanic Group and small pockets of the Pliocene Cockburn Island Formation ("Pecten−conglomerate"). Framed in a geo-paleontological project focused on the James Ross Basin, the firsts prospecting activities were carried out during the last austral summer. Specimens collected during this first stage from the Pecten-conglomerate, allows the preliminary identification of new taxa as Cheilostomata bryozoan cf. "Anasca" and cf. "Ascophora". Subsequently, our project will focus on the Cockburn Island through: 1) A comprehensive study of fossil specimens from the "Pecten-conglomerate" to test the hypothesis of environmental conditions consistent with an interglacial period, and an ice-free coastline, 2) The evaluation of Cockburn Island Formation as a Geo-Heritage topic, and 3) Paleontological fieldwork in the almost vertical cliffs with Cretaceous and Paleogene units. Particularly the Paleocene-Eocene levels, which in contrast to the deltaic/estuarine outcrops of La Meseta Formation in Seymour Island, should have a more continental influence due to its proximity to the source area.

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Glacially driven shelf-to-rise transport from seismic stratigraphy linked to IODP Expedition 379 drill sites in the Amundsen Sea, West Antarctica

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The Amundsen Sea sector of the West Antarctic Ice Sheet is currently losing large amounts of ice, driving hypotheses on collapses during past warm times with similar climatic conditions as predicted for the near future. IODP Expedition 379 aimed to collect sediment cores from the continental shelf and rise of the Amundsen Sea Embayment in order to analyse records of changes in glacially driven sedimentation to decipher and analyse major phases of intense ice sheet advances and retreats across the shelf. The existing seismic network is linked to the two sites drilled on the continental rise during Expedition 379. These drill sites are located on one of the major sediment drifts with one site being near the top of the drift, recovering high-resolution Pleistocene to late Miocene records. An adjacent deep-sea channel and other channels meander from the foot of the continental slope and have transported suspended sediments from the outer shelf into the deep sea, thereby supplying much of the drift deposits. Several connected seismic lines extend from the rise onto the shelf. Our seismic correlation with marker horizons at the drill sites shows that the major progradational sequences of the outer shelf were deposited by glacial advances in the Pliocene, indicating that the WAIS did not advance to the shelf break of the Amundsen Sea Embayment before the Pliocene. Since the build-up of the progradational wedge, deep-sea channel systems developed to large extent and contributed to the formation of most of the sediment drifts on the continental rise.

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Stratigraphy of the Marie Byrd Land sector of West Antarctic Continental Margin: evaluating trends in depositional and oceanographic setting

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Understanding the past evolution of the West Antarctic Continental Margin is critical for informing predictions regarding the future of the West Antarctic Ice Sheet. The climatic and oceanographic setting of the margin is known to have influenced the growth and retreat of the WAIS over time, including potential ice sheet collapse during the Pliocene. However, large uncertainties remain in reconstructions. Two recent IODP expeditions to the Ross and Amundsen Seas acquired core from as far back as the Miocene to revise and constrain models of ice sheet change. However, direct stratigraphic correlation between the two sectors was limited by the lack of geophysical data.

For this reason in 2019, concurrent to IODP-379, the RV «Academic Alexander Karpinsky» undertook an expedition to the Marie Byrd Land sector of the margin, collecting 2260 km of geophysical data. Eight seismic reflection profiles were combined with previously acquired data, to produce a stratigraphic model which could be directly correlated to the IODP sites.

Stratigraphic and geomorphic analysis shows that the sedimentary package has been affected to varying degrees by both downslope processes and depositional processes from oceanographic currents. Notably, there is a strong east-west pattern of deposition which reflects differences in the dominant sedimentary processes between the Amundsen and Ross Seas. These regional differences in the oceanographic setting could revise our current understanding of how the WAIS reacts spatially to climatic changes. Further analysis will look at evidence for ice sheet collapse in the Pliocene and any indication of asynchrony across the margin.

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Seismic characterisation of the seafloor stratigraphy beneath the Ross Ice Shelf near the Kamb Ice Stream grounding line

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Seismic data collection during three recent seasons has resulted in almost 75 km of seismic profiles covering a region just seaward of the Siple Coast grounding line of the Kamb Ice Stream. This region is the focus of ongoing research efforts on the southeastern part of the Ross Ice Shelf supported by Antarctica New Zealand. Seismic imaging in this region is being used to position drilling efforts through the ice shelf and into the underlying seafloor. The layout of the lines was designed to provide regional coverage of the sub-ice-shelf ocean and sediments in a region where Rosetta airborne-gravity data identified a gravity low. Data acquisition through the three surveys seasons has been similar, with a 96-channel seismic system recording symmetric shot records with a 10 m geophone spacing. Shots, frozen in at a consistent depth of 25 m below the surface, vary from 2.4 kg to 0.8 kg, with the lower charge size having significantly improved frequency content. Processed seismic data show a relatively flat seafloor lying beneath the ocean cavity. Subseafloor reflectivity suggests the presence of a subhorizontally layered sedimentary succession at least several hundred metres thick with a number of erosional contacts between stratigraphic sequences clearly identified. There is no clear evidence of a basement reflection in the seismic data. The regularity of the seafloor and underlying sediments suggests that the Rosetta gravity low must have a geological, rather than bathymetric, origin.

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The Polar Rock Repository: A Resource for Glacial Studies

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The Polar Rock Repository (PRR) at the Byrd Polar and Climate Research Center (BPCRC) is an NSF funded facility that provides access to rock, terrestrial drill core, glacial deposits and marine dredge samples from Antarctica and the southern oceans. Currently >54,000 samples are available as no-cost loans for research.

The collection contains more than 700 samples from the Cenozoic Sirius Group. In addition, > 800 specimens are available from other glacial deposits with a concentration in the Dry Valleys. The dredge collections include samples that contain corals/marine invertebrates and marine plants. The PRR online database contains information useful to glacial geologists and biologists by noting locations with biological activity in ancient lakes, soil horizons, dry valleys and glacial surface features.

Typical sample information includes formation, age, weight, surface features, minerals observed, magnetic susceptibility, specific gravity (on request), logistics, publications, field notes, photographs etc. Scientists may request samples and conduct research using destructive techniques. In addition to the physical samples, the PRR archives supporting materials: eg. field maps and photos, air photos, thin sections and any associated bibliography/DOI's.

Researchers may search for samples using the PRR website which uses an advanced search engine to allow scientists to "drill down" into search results using categories and look-up object fields similar to websites like Amazon. Results can be viewed in a table, downloaded as a spreadsheet, or plotted on an interactive map that supports display of satellite imagery and bathymetry layers. Samples can be requested by placing them in the 'shopping cart'.

Facies characterization of early Holocene deglaciation record, IODP Site 1357A, East Antarctic Wilkes Land margin

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We aim to contribute to the understanding of the processes and drivers of marine-based East Antarctic Ice sheet (EAIS) loss and its contribution to global sea level rise and biological impacts during the Holocene deglaciation that followed the Last Glacial Maximum (LGM) (~24 kyr-12 kyr). Holocene sediments above the LGM diamicton at Site U1357 (IODP Expedition 318), located on east Antarctic Wilkes Land margin continental shelf, are 180 m thick, being one of the highest resolution (annual to millennial) sedimentary records in the Southern Ocean close to Antarctica over the last ~12 kyr. Preliminary facies analysis of the Holocene deglaciation sediments (cores 19-20H, 160.22 – 185.45 mbsf) reveals two pulses of sand/silt sediments with ice rafted debris (IRD). These pulses are intercalated within a rhythmic laminated diatom ooze above the poorly sorted gravelly siltstone diamicton. To infer past ice-sheet dynamic, facies characterization is based on high resolution digital images, CT Scans, grain size analyses, and physical properties while congruent paleo-environmental conditions are reconstructed through continuous X-Ray Fluorescence (XRF) geochemical data, diatom counts, HBI biomarkers and biogenic silica data. In addition, additional 14C ages are being processed to constrain the age model.

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Holocene sediment deposition in the Drygalski Basin of the western Ross Sea

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Two gravity cores (GC01 and GC03B) and two box cores (BC01 and BC03) were obtained, respectively, at site DG12-01 (74°43.6'S, 166°42.2'E, 1,028 m) located in the northeastern flank and site DG12-03 (75°12.7'S, 164°14.1'E, 1,244 m) located proximal to the Drygalski Ice Tongue in the Drygalski Basin. Comparison of preliminary data between the box core and the upper part of gravity core confirms that the core-top loss of gravity cores is negligible. Sediment facies of GC01 consists of the faintly-laminated gravelly muddy sand at lower part and the bioturbated mud at the upper part. GC03B consists of the muddy sand with scattered mud chips at the lower part, the sandy mud as the transition interval, and the bioturbated mud at the upper part. In both cores, the bottom sediments are characterized by relatively high MS, large mean grain size, high C/N ratio, low water content, low TOC, low TN, and low biogenic opal. In contrast, the sediment properties of the upper part are opposite to the lower part. Absence of diamicton at the bottom of both cores indicates the Holocene sediment deposition after the retreat of glacier in the Drygalski Basin. Abundant sand and occasional mud chips in the muddy sand facies of GC03B and large number of gravels in the gravelly muddy sand facies of GC01 reflect the continuous supply by floating glaciers during the retreat of glacier. The bioturbated mud facies at both sites signifies the complete retreat of glacier and the seasonal sea ice condition.

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Unique oceanographic and climatic conditions in the Early Oligocene Australian Antarctic Basin: Did enhanced productivity tip the climatic scales towards colder climates?

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The Early Oligocene (~34-27 Ma) is a time of major transformation in the Southern Ocean. The growth of the continent-wide ice sheet at the Eocene/Oligocene Boundary as well as the establishment of a circum-polar water mass exchange modified pre-existing ocean current and sedimentation patterns. This crucial timeframe for understanding the transition and manifestation towards colder climates is not well observed in the deeper Southern Ocean. Our understanding mainly hinges on sparse drill sites located on bathymetric highs. We re-examined all available seismic reflection data in the Antarctic-Australian basin, detecting an enormous, up to 2.1 km thick sedimentary package on the abyssal plain offshore Wilkes Land. By tying this interpretation to adjacent drill sites, we report compacted sedimentation rates of up to 30 cm/kyr during the Early Oligocene. The clear lack of downslope transport mechanisms in the seismic data coupled with clockwise oceanic circulation in the Australian-Antarctic basin point to a non-terrigenous origin of the strata. This depocentre is exceptional within Southern Ocean, considering its size, location and composition. We propose that this massive accumulation of potentially biogenic material is the result of spatial and temporal unique oceanographic and climatic conditions in the Australian- Antarctic corridor. For a brief period, the combination of a newly glaciated continent increasing nutrient supply, a clock-wise ocean circulation transporting warmer waters and creating an upwelling cell, lead to enhanced biogenic sedimentation in the deep sea. The increased productivity and carbon sequestration potentially impacted the reduction of atmospheric CO2-levels, tipping the climatic scales towards colder conditions.

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The roles of turbidity current and glacial dynamics in shaping continental margin, off Prydz Bay, East Antarctica

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The Early Pliocene saw major changes in geomorphology and sedimentation in the Prydz Bay region that produced Prydz Channel and Amery Depression on the shelf and the trough- mouth fan on the upper slope. However, evidence for the state of the EAIS during the Pliocene is sparse and difficult to interpret unequivocally. Marine geological-geophysical data collected from the continental shelf in Prydz Bay, Antarctica, including seismic-reflection data, bathymetry, core records from ODP drilling and gravity coring sites, reveal a complex paleo-subglacial drainage system linked to an offshore depositional regime. Sediment delivery mechanisms at the Prydz Bay are influenced by a number of interplayed factors including canyons-channels, turbidity currents, bottom current, sea level changes, paleo-ice streams, meltwater, and mass-wasting processes because the sedimentary sequences comprise turbidites, contourites and blocky mass transport deposits. The canyons and channels along the Prydz Bay margin act as main conduits for turbidity currents and debris flows that bring sand-sized sediments from the glaciated margins to the deep sea, facilitating slope bypass. Coriolis force is a key factor, which controls the deposition architectures of the intra-channel sedimentation and owing to its effects, turbidity currents build higher levees on the left-hand side in the Southern Hemisphere. However, we noticed that higher levee deposits developed at the right-hand side and erosional features and slumps are occurred on the left-hand side on the Wilkins canyon. To explain this, we propose that a high energetic, strong erosive traction-dominated flow, which is associated with dominantly bypassing channel systems controlled such depositional architectures.

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Reconstructing past ice-ocean changes using beryllium isotopes: assessment in the Ross Sea

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Beryllium isotopes measured in glacio-marine sediment have the potential to record past changes in ice-shelf geometry, ocean circulation and/or meltwater discharge, on a range of timescales. However, reliable application of the approach firstly requires assessment of beryllium isotope concentrations in sediments of known environmental settings. We measured isotopes in a range of modern sediments from across the Ross Sea, and combined these with previous data from the region.

We found that both meteoric 10Be and the 10Be/9Be ratio are able to robustly distinguish between depositional settings. Statistically different concentrations occur between sub-glacial (low 10Be and 10Be/9Be), sub-ice shelf (intermediate 10Be and 10Be/9Be) and open marine (high 10Be and 10Be/9Be) settings. This result differs from that found in Prydz Bay (East Antarctica), where the 10Be was shown to reflect sub-ice shelf circulation patterns rather than depositional environment. We therefore suggest that down-core measurements of beryllium isotopes from the Ross Sea should provide a clear reconstruction of past changes in ice-shelf geometry. Lower magnitude variability in isotope concentrations could reflect changes in ocean circulation or meltwater discharge.

Further work is required to test: 1) Are beryllium isotopes measured in sediment from beneath the Ross Ice Shelf an indicator of sub-shelf circulation or the distance from the grounding-line/calving-front?; and 2) Does variability in beryllium isotopes reflect changes in meltwater discharge?

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Ocean-driven non-linear glacier retreat during the Holocene: southwestern Ross Sea, Antarctica.

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Recent grounding-line retreat, dynamic thinning and mass loss in Antarctica has been attributed to oceanic warming. Episodic grounding-line retreat and rapid thinning also occurred in the southwestern Ross Sea during the Holocene, despite relatively cold ocean temperatures. The exact driver of ice loss at this time remains uncertain, with large-scale ice sheet models unable to simulate the timing and rate of thinning indicated by geological data in southwestern Ross Sea.

Here we apply the 2D finite-element ice-flow model Úa to investigate the role of ocean temperature and bed geometry in the deglaciation of the southwestern Ross Sea. Model runs were constrained by onshore records of ice sheet thinning at Mawson and Mackay Glaciers, as well as offshore ages of grounding-line retreat and inferences from seafloor geomorphology.

Our experiments demonstrate that the bed geometry controlled the spatial pattern of grounding-line retreat. Topographic pinning points limited the rate of ice loss until retreat progressed beyond a bathymetric threshold. Additionally, ocean thermal forcing determined the timing of this ice loss. Enhanced ocean-driven melt is required during the Early-to-Mid Holocene in order to replicate the records of deglaciation. Such oceanic changes are possibly linked to the production of High Salinity Shelf Water, and could explain similar episodes of ice loss that are recorded elsewhere in Antarctica at this time.

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Laminated sediments in core RS15-LC42 in the central basin of the Northwestern Ross Sea: Preliminary microscopic results

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An 11.75 m-long core RS15-LC42 was collected at the water depth of 2084 m in the Central Basin (71°49.40'S, 178°34.76'E) of the northwestern Ross Sea. Core LC42 consists of three major sediment facies: IRD-poor bioturbated mud, IRD-rich massive mud, and laminated mud. These facies are intercalated throughout the core and, particularly, 8 laminated mud facies were distinct, despite the different thickness from about ten cm to more than 2 m. In this study, we focus on the uppermost laminated mud (LM1). LM1 occurs between 150 cm and 175 cm downcore with the upper and lower boundaries to IRD-poor bioturbated mud. The lower boundary seems clear whereas the upper boundary is fairly bioturbated. A series of a few mm to a few cm-thick light and dark laminae were interlayered to form LM1. At 165-167 cm downcore, thin section was made for the microscopic observation and polished section was prepared for SEM examination. Based on microscopic observation, the thin light layer seems coarser than the thick dark layer. The SEM examination reveals that the coarse-grained light layer consists of angular to subangular silt particles including silt-sized aggregates of fragmented diatoms. In contrast, the fine-grained dark layer is composed of mostly clay-sized clastic particles enriched with the very tiny diatom pieces. Thus, the formation process and related depositional condition of these laminated sediments will shed light on understanding the advance and retreat of glacier and its role to the depositional process in the slope basin of the northwestern Ross Sea.

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Pre-site surveys and plans for deep geological drilling in Antarctica: Observations beneath the Ekström Ice Shelf (Sub-EIS-Obs), Dronning Maud Land, East Antarctica

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During previous seasons, pre-site seismic surveys have taken place on the Ekström Ice Shelf (EIS), with the primary goals of establishing a chronostratigraphic framework for the sub-ice-shelf sedimentary record and gaining a better understanding of the cryosphere/ocean/sediment interactions, thresholds, magnitudes, and rates of previous ice-sheet changes in this area. The sediments cover the Explora Wedge, a syn-rift volcanic deposit. Supposed ages for the sedimentary sequences range from Late Mesozoic to Quaternary. From vibroseismic profiles, we selected sites for seafloor sampling through up to 332m ice melted by Hot Water Drilling (HWD) and 722m depth below the ice shelf surface. First preliminary results for stratigraphic age (diatoms and absence of pollen) from core catcher samples indicate ages between 2.5 and 10 Ma.
Last deglacial sediments below the EIS display high carbonate contents from prevailing sessile benthic organisms, mainly bryozoans. One ^{14}C age constraint from a surface bivalve shell provided a minimum age for the grounding line retreat at Site EIS-2 of 7098±98 ^{14}C years BP (uncorrected). Petrographic and geochemical analyses of clasts offer information about the geology of the outcropping strata and the ice-covered hinterland.
We plan to establish an international consortium to deploy deep drillings through the sediments overlying the Explora Wedge and the wedge itself. We expect these sediment sequences to reveal the history of polar amplification and climate changes in this part of Antarctica, as well as the build-up of the East Antarctic Ice Sheet during past climates. We further aim at deciphering its Cenozoic and future variability.

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Late Pliocene to recent variations in ocean heat flux to the Ross Sea continental shelf interpreted from XRF sediment geochemistry, IODP Site U1523

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International Ocean Discovery Program (IODP) Site U1523 was cored on the outer continental shelf of the eastern Ross Sea. Sedimentation at this site is dominantly controlled by currents, recording variations in alongslope (Antarctic Slope Current [ASC]) and downslope (Ross Sea Bottom Water) current flow from the late Miocene to present. In the Ross Sea, the ASC acts as a barrier to the transfer of warmer modified Circumpolar Deep Water onto the continental shelf and therefore changes in ASC strength play a role in penetration of warm water in this region. Here we target the upper Pliocene to recent record to examine changes in current strength as a proxy for oceanic forcing (heat flux) using sediment geochemical records. We collected X-ray fluorescence (XRF) core scanning data and calibrated it with major and trace element analyses. We also measured total carbon, organic carbon, and carbonate content on select samples. These data allow us to construct high-resolution records of major and trace element sediment composition. Initial results show cyclical variations in some records. Silica and barium are anticorrelated over some intervals, whereas zirconium and titanium typically show distinct peaks interspersed with intervals of little variation. Carbonate content is generally low (0.5–5 wt%), although a few samples record higher carbonate content (up to ~12 wt%). We use multivariate statistical analysis to identify distinct geochemical signatures that may represent different water-mass sources. Our data will be combined with other records to elucidate changes in ocean heat flux and its influence on Antarctic ice-sheet stability.

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Evaluating and applying the sea-ice biomarker lipid IPSO25 on sediments from western Antarctic continental shelves

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Over the past decade, an organic geochemical biomarker lipid, i.e. a highly branched isoprenoid (HBI) diene called $IPSO_{25}$ (Ice Proxy of the Southern Ocean with 25 carbon atoms; Belt et al., 2016), has gained pronounced attention as a proxy for sea-ice reconstructions in Antarctica. To further evaluate the reliability of this proxy, we investigated several seafloor surface sediments from the Amundsen Sea, the Antarctic Peninsula and the Weddell Sea and compared the proxy-based sea-ice reconstructions to satellite data and modelling outputs.

We then applied the $IPSO_{25}$ proxy to a marine sediment core recovered from inner Pine Island Bay on the Amundsen Sea Embayment (ASE) continental shelf. Pine Island Glacier, which drains the West Antarctic Ice Sheet (WAIS) into the eastern ASE, is regarded as a hotspot for rapid mass loss of the WAIS and may contribute 3.5 – 10 mm to sea level rise over the next 20 years (Favier et al., 2014). Thinning of the glacier is attributed to the basal melting of its floating ice shelf by warm Circumpolar Deep Water upwelling onto the continental shelf. We conducted organic geochemical biomarker analyses, which provide valuable insights into the sea-ice conditions in the ASE and the evolution of Pine Island Glacier over the Holocene. Therefore, we considered $IPSO_{25}$ alongside a phytoplankton biomarker, subsurface temperatures derived from GDGT analysis and sedimentological parameters for reconstructing palaeo sea-ice coverage. In order to provide semi-quantitative palaeo sea-ice estimations, we further applied and evaluated the recently proposed $PIPSO_{25}$ index (Vorrath et al., 2019).

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Reconstructing past Totten Glacier expansion and retreat using diatom and radiolarian based temperature reconstructions.

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The Totten Glacier drains more ice than any East Antarctic glacier, contains the equivalent of 3.5m sea level rise, and rests on bedrock below sea level. Recent observations have shown that basal melting of the glacier is due to warm water masses entering the cavity beneath the glacier via a deep submarine channel. Changes in ocean heat flux likely explain observed Totten Glacier melt rates, so reconstructing past ocean temperature may provide insight into how the glacier has changed in the past.

The Totten Glacier drains at the Sabrina Coast. Marine sediment cores from the continental shelf and slope are valuable when estimating past ocean temperatures and ice-ocean interactions. Well-preserved siliceous microplankton skeletons (namely diatom frustules and radiolarian tests) in Sabrina Coast sediments are useful when reconstructing past ocean conditions, particularly considering carbonate microfossils are virtually absent.

This poster will present Holocene temperature reconstructions of surface water using diatom-based transfer functions, and at depth using radiolarian-based transfer functions, to help identify possible warm water incursions during the Holocene. Other proxy evidence will be relied upon to investigate the presence/absence of sea-ice and timing of past melt water pulses and to link SST estimates and periods of retreat and expansion.

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Contourite drifts and paleoceanography in the Powell and Jane Basins, north-western Weddell Sea

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This research is based on the seismic data (more than 30000 km) collected in the Northern Weddell Sea by many countries/organizations and available from the Seismic Data Library System as well as on the new data acquired in 2018 by the Russian Antarctic Expedition. Seven major seismic horisons were identified in the sedimentary cover of the north-western Weddell Sea. Ages of the horizons (c. 27, 20, 18, 14, 12, 6 and 3 Ma) were suggested on the basis of ODP drilling and our knowledge about the past environmental conditions in the West Antarctica (seismic stratigraphy generally follows the previously created models with minor changes). Different types of contourite drifts were identified in the Powell and Jane Basins. Drift distribution and current-controlled moats/channels allow us to reconstruct the bottom water circulation in the Late Cenozoic. In the Powell Basin, bottom currents originated soon after the basin opening (between 25 and 20 Ma). Major depositional changes in the studied region are marked by the horizon '5' (c. 12 Ma) which correlates with the start of full West Antarctic glaciation and arisen connection between the Weddell Sea and the Scotia Sea. Current-controlled (buried and recent) moats, channels and marginal valleys are well identified and continuously mapped along the slopes of continental margins and basement highs (sea mounts and the Jane Volcanic Arc) showing the position of bottom current cores. This study was supported by the Russian Foundation for Basic Research, Project 19-05-00858.

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The SWAIS 2C Project - Sensitivity of the West Antarctic Ice Sheet in a Warmer World

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Antarctic ice sheet dynamics remain the largest uncertainty in projections of future sea level rise. The SWAIS 2C Project is a new international effort that aims to understand past and current drivers and thresholds of WAIS dynamics to improve projections of the rate and size of ice sheet changes under a range of elevated greenhouse gas levels in the atmosphere and associated average global temperature scenarios to and beyond the 2°C target of the Paris Climate Agreement. A primary goal of SWAIS 2C is to acquire geological records of WAIS extent from past intervals of warmth including Quaternary super-interglacials. Previous drilling by the Deep-Sea Drilling Project (DSDP), Ocean Drilling Program (ODP), and recent International Ocean Discovery Program (IODP), MeBO, and ANDRILL recovered stratigraphic records of past ice sheet behaviour across the mid to outer continental shelf. Similarly, the response of WAIS to past warmer-than-present climates has been inferred from far-field globally-integrated records of sea level and ocean δ18O. We will utilize new drilling technology to obtain a sedimentary history of past ice sheet dynamics at two locations (Kamb Ice Stream and Crary Ice Rise) along the Siple Coast in the West Antarctic interior. Geological records from this location have proven difficult to obtain but are critical to better constrain marine ice sheet sensitivity to past and future increases in global mean temperature up to 2°C.

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Late Miocene to late Pleistocene paleo ice flow to the central Ross Sea from detrital zircon U/Pb geochronology

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In 2018, International Ocean Discovery Program Expedition (IODP) 374 retrieved sediments from a ~695.74 m succession of upper Miocene to recent strata at Site U1522 located in the Glomar Challenger Basin, Ross Sea. With the goal to unravel till input from East (EA) and West Antarctica (WA), 10 till samples were selected to collect U/Pb ages by LA-ICPMS on the 250-63 µm size fraction (200-300 grains per sample to maximize detection of small age populations).

Four samples from ~700 to 540 m CSF-A (core depth below sea floor) with late Miocene depositional ages have distinct age peaks at 600-500 Ma, 350-320 Ma, 240-160 Ma, 100 Ma, and 30-40 Ma, similar to ages reported in the Swanson Formation, Ford Granodiorite, WA ice streams and Byrd Coast Granite. Ages 30-40 Ma are not well documented elsewhere and could be associated with felsic phases of early McMurdo Volcanics or with younger WA volcanism. Three late Miocene-Pliocene samples (~480-340 m CSF-A) have a Triassic-Permian signal similar to the upper Beacon Supergroup. However, 600-500 Ma ages similar to the Swanson Formation or Lower Beacon remain strong. Three samples (~220-3 m CSF-A) of Plio-Pleistocene age have similar zircon age populations to one another and predominantly resemble ages from EA Nunataks, with a small 100 Ma (i.e. WA) peak present.

Our analyses on till deposited on the central Ross Sea continental shelf provide evidence for a change from predominantly WA sediment input to a more significant EA contribution over time.

Rapid Denudation of West Antarctica during the Early-Middle Miocene

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Most of the West Antarctic Ice Sheet is grounded well below sea level; this geometry strongly influences the response of the ice sheet when ocean warmth is supplied to its margin. Topographic reconstructions suggest that West Antarctica largely fell below sea level during the early-middle Miocene, but the timing of this transition remains poorly constrained despite its considerable impact on the ice sheet's susceptibility to changing ocean conditions.
In 2018, International Ocean Discovery Program Expedition 374 recovered 411.5m of predominantly lower-middle Miocene sediment at Site U1521 on the middle-outer continental shelf of the Ross Sea. To unravel ice sheet behaviour during this period, we consider the provenance of sediments from the lower part of Site U1521, which were deposited ~18-16.7 Ma, using various geochemical methods (zircon U-Pb dating, hornblende/biotite Ar-Ar dating, fine-grained Sr and Nd isotopes). These data have been augmented by clay mineralogy and petrographic characterisation of gravel-sized clasts, and integrated with palynology, lithofacies and seismic facies interpretations.
Whilst some units have a distinct geochemical and petrographic fingerprint characteristic of a central Transantarctic Mountain source region, 180m of sediment contains abundant reworked dinoflagellates and was primarily derived from West Antarctica. This West Antarctic sediment was deposited from ~17.8-17.4 Ma, coinciding with a period of increased obliquity sensitivity. This well-defined shift in provenance implies a significant change to ice sheet flow. We suggest this is linked to the lowering of the West Antarctic topography below sea level, heralding the transition to the more sensitive marine-based ice sheet observed today.

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Mid-Miocene and Pliocene Antarctic ice sheet characteristics and stability deduced from lava—ice interactions at Mason Spur and Helms Bluff, McMurdo Sound, Antarctica

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Assessing variations in Antarctic ice sheets is fundamental in quantifying future climate and sea level change and is largely reliant upon numerical modeling. Critically, some fundamental but unknown aspects of past ice sheet conditions, such as ice thickness and thermal regime (ice sheet stability), are best answered by looking at lava—ice interactions in a field of study termed glaciovolcanology. Such parameters are necessary for accurate ice sheet and sea level modeling. To that end, glaciovolcanology studies have been undertaken in the southwest Ross Sea of southern Victoria Land, at Mason Spur and Helms Bluff. These studies compliment glaciovolcanology studies undertaken nearby at Minna Bluff and in northern Victoria Land, and offshore drilling studies by ANDRILL and the Cape Roberts Project. Mason Spur exposes part of a Cenozoic eruptive centre in McMurdo Sound, c. 100 km southwest of Ross Island. It was active c. 12 to 11 Ma during warming immediately post the Mid-Miocene Climatic Optimum and records evidence of eruption in the presence of either free water, snow or alpine glaciers. Nearby Helms Bluff exposes another volcanic feature erupted at c. 4.5 Ma. It includes ʻaʻa lava-fed delta formations with morphologies typical of emplacement beneath ice. The outcrop allows an estimation of the minimum thickness of the past overlying ice sheet and records wet- versus dry-based glaciation conditions. In conjunction with nearby onshore and offshore records, these studies inform time-slice reconstructions of Neogene ice sheet conditions, including during periods of volcanic eruption not well represented in marine drillcore records.

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Summer sea-ice variability in the eastern Weddell Sea during the last glacial stage as recorded in snow petrel stomach oils ('mumiyo')

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Antarctic sea ice is a critical component of the climate system, affecting a range of physical and biogeochemical feedbacks, and supporting unique ecosystems. During the last glacial stage, Antarctic sea ice was more extensive than today. However, uncertainties in both empirical data sets and climate models over the seasonal distribution and character of the sea-ice pack limit our understanding of sea-ice drivers, ecosystem response, and climate impacts. Here, we exploit a unique biological archive of conditions in the sea-ice pack: the preserved remains of regurgitated snow petrel stomach oils (sometimes referred to as ‘Antarctic mumiyo’), deposited on nunataks above the ice sheet. We present results from a sequence recovered from the Lake Untersee Oasis, central Dronning Maud Land (71°20.2’S, 13°23.6’E), which records snow petrel foraging in the eastern Weddell Sea. By linking dietary signals in the stomach oils to modern feeding habits, we demonstrate centennial-scale variability to the summer sea-ice pack close to the Antarctic continent early in the last glacial stage (ca. 24.5-30.7 cal. ka. BP). By identifying the presence and evolution of open waters (‘polynyas’) within the sea-ice pack, the results challenge existing hypotheses which emphasise the development of an extensive, thick, multi-year ‘sea-ice cap’ as the key for positive sea ice / climate feedbacks during glacial stages.

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Variations in Antarctic Ice Sheet extent in the late Miocene to Pliocene: Results from IODP Site U1522 on the Ross Sea Continental Shelf

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The marine-based West Antarctic Ice Sheet is particularly vulnerable to increasing ocean temperatures; however, lack of ice-proximal records limits the ability of modelers to use paleoclimate data to better constrain future ice-sheet retreat and sea-level rise. International Ocean Discovery Program (IODP) Expedition 374 cored 702 m of Neogene sequences at Site U1522 on the Ross Sea continental shelf, recovering ~280 m of core (40%). The site targeted a seismic sequence of massive and laminated acoustic facies interpreted as interbedded glacial, glaciomarine, and open-marine deposits to provide insight into past ice-sheet behavior. Our study targets the consolidated sediments below 200 mbsf, which consist of upper Miocene to Pliocene diatom-bearing to rich sandy to muddy diamictite, mudstone, and diatomite. We present X-ray fluorescence (XRF) core scanning results, calibrated with major and trace element analyses that provide a high-resolution record of sedimentary geochemical variations. XRF bromide counts correlate strongly with total organic carbon content and we use these data as a proxy for paleoproductivity. We combine all of these data, together with sedimentary facies analyses, to evaluate late Miocene to Pliocene changes in relative ice sheet proximity, sediment provenance, and paleoproductivity. Initial results reveal cyclical geochemical variations that may reflect changes in provenance. We also use downhole logging data to assess lithological changes across core gaps, including an unrecovered interval between 230 and 250 mbsf that likely corresponds to the mid-Pliocene Warm Period. This integrated approach allows us to develop a better understanding of Antarctic ice sheet sensitivity in a warming world.

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Cryptotephra in marine sequences of the Ross Sea, Antarctica: implications and potential applications

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Marine sediments of Antarctica contain tephra, fragmented material produced by explosive eruptions of Antarctic volcanoes and widely dispersed by wind. Tephra are preserved specially when sequences suffer small disturbance and sedimentation rate are high. If fingerprinted, dated and linked to a volcanic source, tephra become time-synchronous markers for independent correlations between geological archives. Tephra are also significant for volcanological reconstructions to derive the type, magnitude, age and recurrence of eruptions. Tephra record can be significantly extended by examining successions for the presence of cryptotephra (non-visible tephra). These are essential to increase the number of eruptions recognizable of any magnitude and in distal occurrences. Recently, for the first time in Antarctica, a cryptotephra record was found in a core from the Joides Basin (Ross Sea; Di Roberto et al. 2019).
This discovery widens the tephra research possibilities, allowing far-reaching objectives to be tackled. On these bases, an innovative and multi-disciplinary project called CHIMERA - CryptotepHra In Marine sEquences of the Ross Sea, Antarctica: implications and potential applications - granted by PNRA proposes to: 1) re-examine marine sediment cores located in the continental shelf basins of the western Ross Sea; 2) identify, date and fingerprint cryptotephra intercalated in these marine sequences; 3) make marine cryptotephra easily identifiable as a stratigraphic markers; 4) synchronize and correlate these levels with Antarctic tephra archives extrapolating information into regional/continental framework and 5) use these stratigraphic markers for the paleoenvironmental reconstructions, mainly addressed to the ice shelf oscillations during the different glacial/interglacial conditions of the Late Quaternary.

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Deglacial dynamics in the Ross Sea (Antarctica) revealed by the occurrence of the planktic foraminifer Neogloboquadrina pachyderma

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Ice shelves are very sensitive to climate variability as their dynamic change is related to atmospheric and oceanic warming/cooling. The dynamics of the Ross Ice Shelf, the largest in Antarctica, have been investigated by several researchers, however, the timing of its retreat from the Last Glacial Maximum (LGM) is still under debate, mainly due to a lack of robust marine chronostratigraphy. Since calcareous organisms are rarely preserved in the Antarctic sediments, possible ages are often based on acid-insoluble organic matter, leading to several problems mainly concerning the incorporation of reworked organic matter. For this reason, the recovery of sediments containing continuous occurrence of calcareous foraminifers can help reconstruct past glacial dynamics in the Ross Sea with a robust age model. Neogloboquadrina pachyderma is the only calcareous planktic foraminifer able to live in polar oceans, surviving in brine channels within sea-ice under hyper-saline and low temperature conditions. The distribution of N. pachyderma in the Antarctic continental margin enables to test models of ice shelf dynamics and water mass variations. We document intervals with an abundant occurrence of well-preserved N. pachyderma (juveniles and adult forms) from the deglacial sedimentary sequences in the northern Drygalski Basin and Hallett Ridge (Western Ross Sea). We discuss N. pachyderma habitat, also considering data of benthic foraminifers, diatoms, and stable isotopes. We suggest that co-occurrence of large N. pachyderma tests and abundant juvenile forms in the deglacial sediments reflect open water conditions and/or variation in the duration and coverage of seasonal sea ice.

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Initial Geologic Results from Thwaites Glacier Offshore Research (THOR) 2019 and 2020 Field Seasons

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Uncertainty in sea-level projections arises from a lack of understanding of how the West Antarctica Ice Sheet will behave in coming decades. Thwaites Glacier, which currently contributes ~4% to sea-level rise, is thinning and accelerating in a deep setting that allows relatively warm Circumpolar Deep Water to melt the glacier base. Significant retreat of Thwaites Glacier will trigger ice loss across the region. Thwaites Glacier mass balance has become increasingly negative, suggesting that unstable retreat may have already begun. These observations motivated a large international collaboration, led by US and UK teams, aimed at understanding the factors that control the stability of Thwaites Glacier.

The Thwaites Offshore Research team conducted three field deployments to study recent glacier retreat. Two cruises of the RVIB N.B.Palmer in 2019 and 2020, combined with sub-ice-shelf sediment coring of 4 sites (2019-2020 season), provide a diverse suite of data along the Thwaites and Pine Island glacier margins. Thwaites Glacier retreat allowed surveying of previously unmapped seafloor in 2019. Major calving of Pine Island Glacier in 2020 allowed surveying in areas that were only accessible by ice-shelf coring previously. Extensive multibeam surveys, 3.5 kHz subbottom and high-resolution seismic profiles, and ~100 sediment cores were collected to investigate properties of the bed from which the glaciers retreated.

The bathymetry reveals troughs that route Circumpolar Deep Water to Thwaites Glacier and bedforms that record past ice-flow. Sediments record glacier retreat and ocean interaction, extending the instrumental record several thousand years through analysis of sediment properties, microfossils, and porewater.

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Sea ice variability across glacial-interglacial cycles in the Weddell Sea

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Multi-proxy investigations of gravity cores recovered from the Antarctic continental margin in the Weddell Sea sector provide for an assessment of sea ice conditions, water temperature and primary productivity variability 1) during the last deglacial at the continental slope off Atka Bay in the northeastern part of the Weddell Sea and 2) across the last glacial-interglacial cycles in the Powell Basin (western Weddell Sea) and proximal to the Riiser Larsen Ice Shelf in the eastern Weddell Sea. Highly branched isoprenoids (HBIs), glycerol dialkyl glycerol tetraether (GDGT) proxies and the recently proposed PIPSO25 index (Vorrath et al., 2019) are used to track past sea ice and ocean temperature fluctuations. These biomarker records are further complemented by XRF and physical property data which support the identification of linkages between ocean and ice-shelf dynamics. Radiocarbon dating and consideration of ice core data finally support the development of core chronologies. Distinct variations in the abundance of the sea ice proxy IPSO25 (Belt et al., 2016) at all three sites point to rapid changes in sea ice cover with potential implications for primary productivity, dense shelf water formation and ice-albedo feedback mechanisms during crucial time intervals of climate warming.

References

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Towards better definition of the age frames and palaeogeography of the oldest Cenozoic glaciations in West Antarctica: isotopic ages of selected volcanogenic series and erratics from King George Island.

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Isotopic studies were carried out in the central part of King George Island. Selected mafic to intermediate igneous rocks were sampled for this purpose. Single-grain U-Pb dating of zircon from andesitic basalts and andesites was controlled by a whole rock 40Ar-39Ar data. The U-Pb isotope dating was also performed on zircons from nine erratic pebbles of different rocks that were found in the tillite of the Polonez Cove Formation. The new age determinations allow to more precise and credible stratigraphic correlation of glaciogenic rocks that intercalate in some places the magmatic succession of King George Island. For example, some volcanogenic formations, considered previously as Cretaceous in age, were emplaced or deposited in fact during the Eocene when volcanic processes were the most intense there. The U-Pb isotope age spectrum obtained from the erratics allowed to define the areas of their derivation and consequently the way of migration of the Polonez ice sheet in West Antarctica. Our studies indicate that most of K-Ar age estimations in West Antarctica cannot define a real age of magmatic rocks and they should be verified by much more credible Ar-Ar or (in the rocks with zircon) integrated U-Pb and Ar-Ar data.

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SDLS as a tool for collaborative data sharing and discovery for understanding the tectonic, geology and paleo-environments of Antarctica

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Acquiring marine multichannel seismic data is an expensive and difficult task, especially in polar environments. In 1991, Antarctic Seismic Data Library System (SDLS) was created under the mandates of the Antarctic Treaty System (ATS) and the auspices of the Scientific Committee on Antarctic Research (SCAR) to provide open access to Antarctic multichannel seismic reflection data (MCS). The goal of the SDLS is to preserve access to the valuable multi-channel seismic data, share information about existing data, and promote collaboration between researchers from different countries and institutions. By doing so, the SDLS maximizes the use of existing data and avoids duplication of survey efforts. The SDLS provides access to the data through library branches worldwide and through a web portal (https://sdls.ogs.trieste.it/), which provides access to unrestricted MCS data in the library. We will present recent updates of the SDLS and provide examples of its use. Today, SDLS holds over 330,000-line km from 129 seismic surveys. The data and resulting cooperation have been a critical basis for scientific progress of the Antarctic marine geoscience community including preparation for numerous ODP and IODP drilling campaigns, tectonic studies, circum-Antarctic sediment distribution, and paleobathymetry analysis.

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Obliquity paced oscillations of the Ross Ic Shelf during the Quaternary

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The frequency of Antarctic glaciations during the Quaternary are not well understood. Benthic oxygen isotope records provide evidence for eccentricity paced global ice volume changes since c. 800 000 years and the ice core records (such as EPICA) also appear to have 100 000 year cycles over the last 800 000 years.

Here we present results from the 6.21 m long, NBP03-01A-20PCA sedimentary record from the Ross Embayment. Sediments comprise mud with numerous clasts and paleomagnetic analyses revealed magnetic reversals C1n-C1r.1r-C1r.1n-C1r.2r which have corresponding ages of 773 ka, 990 ka, and 1070 ka.

Time series analysis of a Anhysteretic Remanent Magnetisation (ARM) data, which are controlled primarily by the concentration of magnetic minerals, revealed strong obliquity paced cycles between c. 800 ka and 350 ka. The presence of obliquity cycles prompted us to carry out core scanning XRF and grain size analyses. We identified obliquity paced cycles in the titanium elemental data over the same period which we suggest represent variations in the terrigenous material in the core. Weaker obliquity cycles are also present in the >2mm IBRD fraction which we suggest is controlled by the proximity of the ice shelf front.

Our data indicate that Ross Ice Shelf calving line advance and retreat cycles were paced with obliquity until at least 350 ka and that the mid-Pleistocene transition occurred later in the Southern Hemisphere than in the North.

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Stratigraphic architecture of Ross Sea sequences reveals nature of ice sheet dynamics during the early to middle Miocene

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Ice sheet oscillations during early-middle Miocene, are intermittently preserved in the sedimentary record on Antarctica's continental shelf, with widespread erosion resulting from the ice sheet advance. Seismic reflection data and deep drilling sites from DSDP leg 28 and IODP Expedition 374 located along the present-day middle continental shelf of the central Ross Sea, indicate the presence of expanded sections of the early-middle Miocene period. These expanded sections hold key evidence for the reconstruction of the Antarctic Ice Sheet oscillation during this period, including the Miocene Climate Optimum (MCO ~17-14.5 Ma), as well as large erosive surfaces associated with ice sheet advance both prior to, and following the MCO. Through correlating core, wireline log and reflection seismic data we reveal marked local variability in the sedimentary record of the Ross Sea continental shelf, which we interpret as evidence of a highly dynamic ice sheet. Here, we look at the seismic architecture of sediment packages associated with ice sheet advance and retreat, and provide preliminary drill core constraints for seismic isopach mapping on how changing ice masses through time influenced sediment deposition. Periods of major ice flow over the basins are revealed by the formation of prograding wedges. Ice sheet retreat is typically marked by high velocity seismic units associated with chert layers and diatom-rich muds documented in the drill core sections. Overall, our research shows several periods of diachronous ice sheet expansions in the Ross Sea prior to, and following the MCO.

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Diatom assemblage variability over the last two glacial cycles in Adelie Land, East Antarctica

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Relative diatom abundance is used together with sedimentological and geochemical data to reconstruct sea-ice cover and surface water productivity over the last two glacial cycles, in a sediment core from the WEGA channel, on the Adelie Land continental slope. The core site is 3,000 m below sea level, approximately 150 km north off the shelf edge, over 250 km from the present-day ice sheet grounding line and is affected by Adelie Antarctic Bottom Water down slope flow. Today, sea-ice cover occurs for part of the year and high productivity occurs in polynyas to the north of the site. The core contains six meters of alternating layers of interglacial and glacial deposits dating to the MIS 7 interglacial (~240 ka), each interval consisting of varying amounts of both hemipelagic and transported shelf sediment. The interglacials are characterised by high productivity (biogenic silica 8-22%) and dominance of Thalassiosira antarctica resting spores (60-70%) suggesting open marine environment. However, the glacials, MIS 2-4 and MIS 6, differ, with MIS 4-2 showing higher (biogenic silica 3-18%) and MIS 6 lower productivity (biogenic silica 3-6%). MIS 2 is characterised by relatively high levels of Thalassiosira antarctica (20-30%) and an increase in Eucampia antarctica (18-62%), including an increase in the sea-ice proxy terminal/intercalary valve ratio (0.2-0.8). Open water diatom species persist during all climatic stages, from MIS 5e to Holocene, suggesting polynya continuity within the Adelie region during the last glacial cycle.

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Influence of topography, substrates and meltwater outbursts on active icesheet retreat during the Late Holocene, offshore Windmill Islands, Antarctica

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The post-glacial history of the East Antarctic ice sheet is not well-known or understood. High resolution multibeam bathymetry from the nearshore region of the Windmill Islands, East Antarctica, reveals a suite of seafloor features recording two major readvances of the Law Dome ice margin during the Late Holocene. Readvance of this ice margin is likely activated by meltwater sourced from episodic jokhulaup outbursts, as observed recently in the region. A complex landform record of moraines, crevasse squeeze ridges and flutes reveal strong topographic and substrate control on the pattern of ice sheet advance and retreat. Cross-cutting relationships between moraine ridges within sediment-floored troughs and embayments provide evidence of active ice sheet retreat, with recession punctuated by phases of readvance, consistent with forcing from episodic meltwater outbursts. The complex pattern of retreat likely reflects the presence of a soft, deformable bed beneath the ice within the troughs and embayments, which promoted greater forward movement of the ice during readvance. In contrast, hard beds of highly fractured crystalline bedrock lack streamlined bedforms, indicating that the retreating ice mass was slow moving or static over these features and less responsive to external drivers forcing periodic readvance during overall deglaciation. This research provides a new understanding of the dynamic retreat of the Law Dome ice sheet; a style of retreat previously not recognised for the seemingly stable East Antarctic ice sheet.

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Chronostratigraphic integration of Neogene sequences from the subantarctic Pacific Ocean: Initial results from IODP Exp. 383, Dynamics of the Pacific Antarctic Circumpolar Current

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Excellent chronostratigraphy is essential for the development and comparison of paleoceanographic reconstructions across Neogene climate transitions. However, the calibration of Miocene and Pliocene biostratigraphic datums in the Southern Ocean has historically been hampered by the presence of hiatuses, compounded by the limited distribution of sediment cores with suitable lithologies to support the development of high-fidelity magnetostratigraphies.

From May-July, 2019, IODP Exp. 383 collected sediment cores from multiple holes at four pelagic and hemipelagic sites comprising a zonal transect along the northern flank of the Pacific Antarctic Circumpolar Current, from 76°41’ W to 125°26’ W. Diatoms, radiolarians, calcareous nannofossils, and planktonic foraminifers provide excellent primary biostratigraphic control for sites U1539, U1540, U1541, and U1543, all of which record apparently continuous accumulation. Central South Pacific Site U1541 (54°13’ S, ~3600 m water depth) spans >8.2 Myr, constrained by 74 biostratigraphic events and anchored by 27 well-defined polarity reversals. Eastern South Pacific Site U1543, on an elevated ridge west of the Chile Trench (54°35’ S, ~3860 m water depth) spans >7.2 Myr, is constrained by 54 biostratigraphic events and 29 well-defined polarity reversals. While Pleistocene shipboard biostratigraphic age assignments from all sites are generally in good agreement with the paleomagnetic reversal stratigraphy, systematic offsets and increasing age uncertainties were identified in the Pliocene and Miocene. Here, we use the exceptional shipboard paleomagnetic records from U1541 and U1543 to evaluate the calibration of select biostratigraphic datums, a first step towards providing a new Southern Ocean reference section for key intervals of the geologic timescale.

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Do turbidite deposits in the Hillary Canyon levee record dense shelf water outflow? Investigating the physical record of Antarctic Bottom Water (AABW) production in the Ross Sea from the late Pliocene (3.3 Ma) through present

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Oceanographic processes on the Antarctic shelf, such as sea ice and polynya formation, result in the formation of dense shelf water (DSW), which contributes to Antarctic Bottom Water (AABW) production. The seaward propagation of DSW to the continental slope can, in turn, trigger turbidity currents that entrain and transport sediment to the deep sea. The resultant turbidite deposits therefore represent a record of AABW outflow history. Our study is focused on IODP Exp 374 Site U1524, located 120 km seaward of the Ross Sea shelf edge on Hillary Canyon levee, one of the largest conduits for AABW outflow. The 280 m thick sedimentary section spans the late Pliocene (3.3 Ma) to recent and contains >3,300 thin (1.5 mm) turbidite beds whose frequency systematically declines up section. We subsampled 100 turbidites and their directly overlying mud and performed grain-size analysis using laser diffraction and x-ray particle sizing, respectively. Median grain size of the turbidites ranges from fine to medium silt (5-30 µm) with an upper end (D90) of medium silt to very fine sand (19- >100 µm). Mud deposits overlying the turbidites have an average silt:clay ratio of 23% and show no systematic variability up section. Sediment composition from XRF data suggests that the turbidites contain a mixture of biogenic (diatom fragments) and terrigenous material. Smear slide analysis of a representative subset confirms an up-section trend of decreasing biogenic content. Our sedimentological record is integrated with other proxy data to investigate AABW history in context of West Antarctic Ice Sheet dynamics.

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The MIS 3 deglaciation of sub-Antarctic Marion Island with cosmogenic 36Cl exposure dating

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Glacial oscillations of the Quaternary provide valuable insights into past and present climate linkages. For the Southern Ocean, the sub-Antarctic Islands provide a valuable terrestrial record of glacial chronologies, since they are unique, not only in size and topography, but also in oceanic situation when compared to other continental landmasses (e.g. Antarctica or Patagonia). Here we present a constrained glacial chronology for Marion Island, southern Indian Ocean, from cosmogenic 36Cl exposure dating. Exposure ages of glacial erosional and depositional features show that island deglaciation was underway before ~50 ka ago and was near completion by the peak of the global last glacial maximum (~20 ka ago). No evidence is found to suggest ice re-advances within this time frame, but minor stand stills are possible. Any Holocene re-advances, e.g. during the Antarctic cooling period, would have been restricted to the island's interior above 900 m a.s.l. This glacial chronology is similar to those of other sub-Antarctic islands (e.g. Kerguelen, Auckland & Campbell, and possibly South Georgia) and a number of mountain valleys elsewhere in the Southern Hemisphere (e.g. in Patagonia and New Zealand). We suggest a combination of declining temperatures, the expansion of the Antarctic ice sheet, the northward migration of the southern westerly wind belt and ocean frontal systems and Marion Island's physiography, created optimal conditions for glacier growth in MIS3 (or earlier) instead of MIS2. Our findings add to evidence that suggest the Southern Hemisphere was in a glacial maxima prior to the global LGM.

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Ostracod record from Pleistocene biogenic carbonate sediments off Cape Adare and IODP 374 U1523 site, a comparison

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Increasing attention has been paid to environmental and climatic change in the scientific literature with a focus on organisms which provide a proxy record of these changes. Ostracods have an excellent fossil record and are among the few groups that can be palaeo-environmentally informative in the marine realm. The NW Ross Sea area off Cape Adare shows carbonate-rich lithofacies, consisting of poorly sorted sandy and gravelly skeletal remains, with a good presence of biological remains. The high ostracods abundance is linked to the water mass circulation with related changes of nutrient content, salinity, sea ice cover and $CaCO_3$ saturation. In addition, the fossil assemblages, as well as textural and geochemical characteristics of marine limestone, contain invaluable proxies that render it possible to reconstruct the evolution of marine ecosystems. Analyses of ostracod fauna from six gravity cores, collected during two PNRA cruises, in 1998 and 2002 respectively, allowed for the determination of the more or less favorable periods when carbonate factories operated in order to produce carbonate sediment and to reconstruct the ice shelf-front oscillation phases and the connected paleoenvironmental / climatic changes. The first results regarding the ostracods recovered from the IODP 374 U1523 site show an equivalent ostracod association to the aforementioned cores, with high quanti/qualitative values in seven units, thus making it possible to compare the environmental and climatic events of the late Quaternary with possible analogous changes which occurred in the last 3.0 Ma.

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Distribution, systematics and biostratigraphy of Pleistocene Radiolaria from core ABP-06, Station-I (Sections 4 and 5) Central Indian Ocean

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Diversified assemblages of radiolaria were recovered from the core ABP-06 of Station-I (Sections 4 and 5). The study area lies between Latitude 110 44.004'S and Longitude 760 3.311'E. The samples were collected at a water depth of 5,236 m. Lithologically, the studied sections are composed of silty clay and siliceous ooze of dark brown colour and containing rich radiolaria. Thirty samples at an interval of 4 cm were used to carry out the detail study. Forty taxa are identified in which 25 Spumellaria and 15 Nassellaria. The distribution of each radiolaria in the sections along with their systematics of stratigraphically important taxa are given. Based on the identified taxa, one radiolarian zone i.e. Collosphaera tuberosa is established. C.tuberosa is made on the appearance and disappearance and the presence of stratigraphically important taxa of this zone. It is observed that both the sections lie between 0.18-0.42 Ma of Pleistocene age.

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Characterization of detrital and diagenetic minerals in a terrigenous sand layer, Resolution Drift, northern Amundsen Sea (Site U1533, IODP379)

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Sediment cores recovered from 4180m water depth on the western flank of Resolution Drift, northern Amundsen Sea, are dominated by hemi¬pelagic muds, but also contain discrete beds of sand or gravel transported downslope from the continental shelf. A deep-sea channel near Site U1533 likely provided the pathway for downslope transport of sediment by turbidity currents, with occasional overspill distributing sediment to the site.

We investigated coarse sand that forms an isolated, sharply bounded layer in Hole U1533D at 39.11m CSF-A depth within thick monotonous mud. The sand horizon is ~2.5cm thick and exhibits normal grading. The detrital mineral assemblage is highly varied, containing quartz, K- feldspar, plagioclase, biotite, hornblende, zircon, rutile, monazite, xenotime, apatite, Fe-Ti oxides, titanite, spinels, and polycrystalline grains. This assemblage is strongly continental in character, reflecting a prevalent source in felsic granitoids. Hornblende and titanite indicate metaluminous plutonic sources; monazite and xenotime suggest more evolved granitoids or metamorphic rocks. U-Pb zircon age dating is in progress and initial results bearing on provenance will be reported.

Also abundant in the sand horizon are light-colored, dumbbell-shaped grains of Mn-oxide, 90 to 150 µm in dimension. Electron backscatter diffraction, used for microstructural-crystallographic characterization, reveals that Mn-oxides are highly crystalline, surrounding micro-grains that provided a nucleation point. The discovery of these forms is significant in light of new recognition of the abundance of particulate Mn in seafloor sediment, to be factored in to global manganese budget, and Mn as a paleoenvironmental indicator (Uramoto et al. 2019; Wu et al. 2019).

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Geochemical characterization and geochronology of distinctive rhyolite tephra and other sparse volcanogenic material in IODP379 deep-sea cores, Resolution Drift, northern Amundsen Sea

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One discrete layer of volcanic ash (tephra) was recovered by IODP379 from ~30m depth within uniform brown marine mud of early Pleistocene age. The coarse ash layer has a sharp base and upper boundary that is gradational over 5 cm into overlying mud. Using spectral and density characteristics, a diffuse cryptotephra was located at comparable depth in a second drill hole approximately 1000 m away. From thin section and electron microprobe analysis, the tephra are coarse (50-300µm) cuspate glass shards with elongated vesicles. The composition determined by EMPA-WDS is rhyolite, with SiO2 > 75 wt.%. 40Ar/39Ar sanidine dating is underway. Preliminary dates are between 2.5 (±0.1) and 2.9 (±0.02) Ma. Based on the discrete tephra horizon, coarse shard morphology, and continuity between two drill holes located 1 km apart, the rhyolite tephra is interpreted as having formed as airfall settled to depth in the deep ocean, at the site >550 km from the Amundsen Sea coastline.
Rhyolite is a rare occurrence in the Marie Byrd Land volcanic province. One notable locality is at Chang Peak-Mt. Waesche in the Executive Committee Range (~1000 km from the drill site). Our comparison of the IODP tephra to rhyolite glass from Chang Peak (sample MB-7.3, J. Smellie) does suggest an affinity to that volcanic center, however the IODP379 tephra differs in respect to the major oxides compositions and age (MB-7.3, 1.308± 0.008 Ma). We conclude that IODP379 tephra record an eruptive event from the Mt. Waesche center that is unknown from surface exposures.

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Origin of detrital and diagenetic minerals in a terrigenous sand layer, Resolution Drift, northern Amundsen Sea (Site U1533, IODP Expedition 379)

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Sediment cores recovered from 4180m water depth on the western flank of Resolution Drift, northern Amundsen Sea, are dominated by hemi¬pelagic muds, with sparse discrete beds of sharply bounded sand or gravel. We investigated an isolated, normally graded layer of coarse sand, ~2.5cm thick in Hole U1533D at depth 39.11m CSF-A. The highly varied detrital mineral assemblage includes quartz, K- feldspar, plagioclase, biotite, hornblende, zircon, rutile, monazite, xenotime, apatite, Fe-Ti oxides, titanite, spinels, and polymineralic grains.

Also abundant in the sand horizon are light-colored spherical- and dumbbell-shaped grains of Mn-oxide, 90 to 150 µm in dimension. Scanning electron microscopy analysis reveals that the Mn-oxides are crystalline and grew radially, rather than concentrically. Enclosed mineral fragments are common, indicating growth in the sand layer, however, it is not clear what material(s) served as nucleation sites. Discovery of a potentially new Mn-oxide form is important, in light of recent descriptions of the presence and extent of Mn particles in seafloor sediment, and their significance for the global manganese budget (Wu et al. 2019; Uramoto et al. 2019).

The mineral assemblage is strongly continental in character and indicative of prevalent granitoid source rocks, some metaluminous, and some metamorphosed. The sand horizon may represent material transported from the continental shelf. A deep-sea channel near Site U1533 likely provided the pathway for downslope transport of sediment by turbidity currents, with occasional overspill distributing sediment to the site. No evidence has been found to indicate other catastrophic processes, such as tsunami or meteorite impact.

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How sensitive are Antarctic Holocene relative sea-level records to late-Holocene glacial fluctuations?

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Traditional models of glacial-isostatic adjustment through the Holocene across much of Antarctica suggest a record of exponentially decreasing rates of relative sea-level (RSL) fall. Such models propose little to no effect of late Holocene ice-mass changes on RSL. However, increasing evidence of glacial oscillations across many parts of Antarctica, including the Antarctic Peninsula, are beginning to mount. What impact, if any, have these oscillations had on Antarctic sea-level records? In this study we review new and existing relative-sea level records from Joinville Island along the eastern tip of the Antarctic Peninsula, the Western Antarctic Peninsula, and the South Shetland Islands that suggest abrupt increases in the rate of sea-level fall through the late Holocene. We propose that these abrupt increases in the rate of RSL fall mark the solid earth response to periods of accelerated glacial retreat during the Holocene. In addition, we examine ground-penetrating radar profiles through raised beaches across the Antarctic Peninsula that also point to periods of relative sea-level rise during the Late Holocene, possibly in response to local glacial advances. These RSL reconstructions point to a dynamic Earth beneath the Antarctic Peninsula supporting recent assertions of a weak rheology underlying this part of Western Antarctica.

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Integrating marine and terrestrial geomorphic records to examine coastal landscape evolution in an Antarctic oasis

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The integration of onshore and offshore mapping reveals relationships between geomorphic features on land and their submarine continuity. This information is critical to understanding landscape evolution, particularly in areas that have experienced alternating glacial, subaerial and marine conditions such as Antarctica. We have used high-resolution imagery and digital terrain models of the marine and terrestrial environments of the Vestfold Hills, an ice-free coastal oasis in East Antarctica, to better understand geomorphic processes including past ice-sheet behaviour. Previous studies of ice dynamics in the Vestfold Hills have been based solely on terrestrial records. Data sources include aerial photography, satellite imagery, and swath bathymetry, as well as ground-based observations.

Mapping the adjacent marine and terrestrial environment highlights the occurrence of similar erosional and depositional landforms, both on land and on the seafloor. Characteristic landforms include knock and lochan topography, boulder fields, moraines, paleoshorelines, and shell-rich marine sediments that were shaped during periods of variable climate and sea level change. Most of the landforms characterising the seafloor developed in glacial or subaerial environments and were subsequently drowned by post-glacial sea-level rise. Significant geomorphological features, such as lakes (lochan), boulder fields, moraines, and paleoshorelines, are now submerged. Similarly, the occurrence of paleoshorelines (marine terraces) and shell-rich marine deposits on land is of particular interest because these landforms can preserve Holocene marine records. Integrating adjacent terrestrial and marine mapping information is crucial for understanding the geomorphological evolution of this rare ice-free coastal area.

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Assessing changes in the detrital sediment record during the Pliocene at the Ross Sea

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The Pliocene is the most recent time in Earth's history when global warmth was sustained longer than any Quaternary interglacial. Understanding ice sheet - climate interactions during the Pliocene provides insights into ice sheet response to ongoing warming. International Ocean Discovery Program (IODP) expedition 374 drilled and recovered 200 meters of Pliocene sedimentary sequences at the Ross Sea. The mid- to late Pliocene interval at Site U1524 is composed of massive to laminated olive gray muddy diatom ooze interbedded with greenish gray muddy/sandy diatom ooze. The insterval shows a cyclicity of the natural gamma radiation measurements within a 200 ky continuous record. For this reason, it was targeted to assess changes in provenance of detrital sediments, in an attempt to verify if changes in mineralogy and isotope composition is paced by orbital parameters. Preliminary XRD results show that the bulk mineralogy of the targeted interval is largely homogeneous and major constituents are quartz, illlite, chlorite and feldspar. Changes in color throughout the sedimentary record are caused by changes in the abundance of these minerals possibly due to variable continental erosion rate and ocean current strength during the time of deposition. Next steps will be to address how Nd varies in the detrital mud fraction to pair this information with mineralogical data.

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An invitation to the international Antarctic research community from Oregon State University's Marine & Geology Repository: Discover new records from the US Antarctic Program's Southern Ocean sediment core collection

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Sediment cores are physical records of past conditions that can be reused to address a wide variety of new research questions, often far beyond the initial purpose for collection. The National Science Foundation's Antarctic Core Collection (ACC) is the world's largest collection of seafloor sediment samples. With over one-hundred and twenty research cruises and expeditions around Antarctica, the collection has grown over the last fifty years to represent the most comprehensive physical archive of Antarctic ice sheet and ocean behavior. In 2018, Oregon State University's Marine and Geology Repository (OSU-MGR) relocated this historic collection of over eighteen kilometers of core samples from the Antarctic Research Facility at Florida State University to the OSU-MGR in Corvallis, Oregon. The relocation project included the construction of a state-of-the-art facility large enough to house the original marine geology research collections, and the ACC, including temperature-controlled space large enough to house the next fifty years of coring expeditions. In addition to long-term storage and archiving services, the new facility includes a core lab large enough to run major sampling parties, five track systems in a designated instrumentation lab, a wet lab with a fume hood for sediment processing, digital description platforms, and a thirty-person classroom. OSU-MGR staff are working to improve the ACC's metadata records in order to build an effective modern inventory using new digital collection management techniques. Current and future curation projects will comply with FAIR data principles, with the goal of making all OSU-MGR collections and associated datasets more easily discoverable online.

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Onshore to offshore glacial reconstruction of Terra Nova Bay, Western Ross Sea: a community work in progress

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With over 100 years of scientific exploration, the Terra Nova Bay area boasts a dense array of data to aid understanding of modern and past glacial behaviour. New terrestrial chronologies from cosmogenic surface exposure dating provide a history of ice-surface lowering for major outlet glaciers, while newly acquired marine geophysical observations and sediment cores constrain the past extent, timing and behaviour of marine-based ice. Using a group GIS, we have initiated new analyses on previously collected samples (Cryptotephra, ramped pyrolosis and meteoric 10Be). Ongoing sedimentary analysis and identification of material for new age constraints combined with recent high-resolution bathymetric data provide new life to cores held in national repositories.

Initial results reveal a mid-Holocene thinning signal along the David Glacier and a series of grounding zone wedges (GZW) consistent with a short-term stagnation of grounded ice which fits with previous studies along the Northern Foothills. X-ray analysis of archived sediment cores near GZWs provide linkages between episodes of onshore glacier thinning and offshore grounding line retreat. Ultimately, these geometric relationships and age constraints inform glacier modelling studies aimed at understanding processes that control glacial behaviour. For example, mapped glacial lineations provide geometric constraints for confluent ice while chronologies from GZWs and terrestrial surface exposure age studies are used to assess the model fit with reconstructed behaviour. This PAIS supported, ‘grass roots’ collaboration compliments ongoing, larger-scale efforts around the Antarctic and provides a forum which allows for open communication timely sharing of data acquisition plans and initial results.

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Rapid thinning of David Glacier in the recent geological past: chronology and controls

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Quantitative satellite observations of ice sheet mass loss span the last four decades, providing limited insights into long-term drivers. Geological records serve to extend the observational record and aid our understanding of ice sheet – climate interactions. Here we present the first millennial-scale reconstruction of changes in David Glacier, the largest East Antarctic outlet glacier in Victoria Land. Thinning profiles derived from 50 10Be and 3He surface exposure samples show that David Glacier experienced rapid thinning up to 2m/yr during the mid-Holocene (~6.5 kyr). Thinning ceased at 6 kyr, suggesting initial formation of the Drygalski Ice Tongue. Our work when combined with new records from adjacent glaciers shows that simultaneous glacier thinning in this sector of the Transantarctic Mountains occurred ~3 kyr after the retreat of grounded ice in the Ross Embayment. The timing and rapidity of the reconstructed thinning at David Glacier is similar to that reconstructed in West Antarctica and Antarctic Peninsula.

We use a glacier model constrained by our geological data to identify the causes of these rapid changes in David Glacier. We show that glacier thinning and marine-based grounding line retreat is initiated by interactions between enhanced sub-ice shelf melting and reduced lateral buttressing, leading to Marine Ice Sheet Instability. Such rapid glacier thinning events are not captured in continental or regional-scale numerical modelling reconstructions for this period. Together, our chronology and modelling suggest a paleo-dynamic thinning event enduring for ~2,000 years, offering insights into the nature and drivers of future ice sheet thinning in Antarctica.

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Preliminary Results of JARE61 Geomorphological Survey at Langhovde and West Ongul Island in Lützow Holm Bay, East Antarctica

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The geomorphological survey in the 61st Japanese Antarctic Research Expedition (JARE61) was carried out at Langhovde and West Ongul Island in Lützow Holm Bay, East Antarctica. The objective of this research is to establish the East Antarctic Ice Sheet history from the Last Interglacial to the Present, especially during the deglaciation.
The mass loss of Antarctic Ice Sheet (AIS) due to the global climate changes will contribute to global sea-level rise, and also the information of present ice-sheet mass balance is required to achieve an accurate projection of AIS behavior against global climate and oceanic changes. The timing and amplitude of AIS change during the deglaciation is essential to assess a glacial isostatic adjustments effect on the present ice-sheet mass balance. However, the difficulty of access in Antarctica make it challenging to obtain field-based evidence of ice-sheet and sea-level change during the deglaciation. In this presentation, we document the preliminary results of geomorphological survey at Langhovde and West Ongul Islands in Lützow Holm Bay. We surveyed the bathymetry of Lake Nurume and coastal area (<150 m water depth) in Langhovde to determine potential sites for collecting samples. In addition, we conducted on-water coring in Lake Nurume and successfully took ~3 m long core and also collect surface sediments and terrestrial cosmogenic nuclides samples. The collected samples contain past sea-level and ice-sheet records of targeted period. This research plan will continue to the next few years, so the collected samples and data will be the first step.

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Deglaciation history of the East Antarctic Ice sheet revealed by exposure ages and marine-lake sedimentary records in Lützow-Holm Bay, Dronning Maud Land

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The East Antarctic Ice Sheet (EAIS) is one of the most significant potential contributors to future sea-level changes. The inflow of modified Circumpolar Deep Water (mCDW) has been focused as one of the major causes of the thinning and mass loss of the Antarctic Ice Sheet. However, the role of the mCDW for the large-scale deglaciation of the EAIS, such as the deglaciation since the Last Glacial Maximum (LGM), remains unclear due to the lack of the geological data. Therefore, highly-resolved reconstruction of the deglaciation history of the EAIS since the LGM is essential to understand the role of the mCDW, which will be a useful analog for calibrate the climate and ice sheet models and refine the future ice sheet retreat projection. In this presentation, we show an overview of our recent activities in the Lützow-Holm Bay, Dronning Maud Land, East Antarctica. Newly obtained surface exposure ages and sedimentary Be-10 records coupled with the previously reported benthic foraminiferal assemblage from Syowa Oasis and Lützow-Holm Bay show a rapid thinning of the EAIS during the early-mid Holocene potentially due to an inflow of mCDW. We, therefore, suggest that it will be a key to obtain both terrestrial and marine-based geological data in the Antarctic margin to understand the potential impact of ocean warming to the rapid and large scale ice sheet melting of the EAIS.

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Oceanic versus bottom water dynamics in the Central Basin, Western Ross Sea (Antarctica), since the Last Glacial Maximum

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The aim of this work is to investigate the dynamics between oceanic and bottom waters recorded in marine sediments collected in the Central Basin (Ross Sea), since the Last Glacial Maximum. In this area, located in the slope area in front of the JOIDES Basin (Western Ross Sea, Antarctica), the dense and cold High Salinity Shelf Water (HSSW) outflows from the shelf margin and mix with the Antarctic Bottom Water (AABW) and the relatively warm Circumpolar Deep Water (CDW) intrudes locally into the continental shelf mixing with dense shelf water (ISW) and HSSW. This study has been conducted in the framework of the STREAM Project (Late Quaternary evolution of the ocean-ice sheet interactions: the record from the Ross Sea continental margin, Antarctica), funded by the twelfth executive program for scientific and technological cooperation between Italy and Republic of Korea (period 2019-2021). Several analyses have been performed on three box cores (X-ray image, magnetic susceptibility, grain-size, TOC, δ13C, biogenic silica, CaCO3 contents, diatom and foraminifer assemblages, tephra identification, 14C dating). Here we revealed that diatom assemblages and grain-size results are important parameters to understand the ocean-bottom water dynamics. In particular, these parameters recorded the entrance of warm oceanic water underlined by the presence of open ocean warm diatoms mainly characterized by Fragilariopsis kerguelensis. On the other hand, levels with high sand content and reworked diatoms represented by Paralia sulcata, a fossil coastal taxon, suggest a strengthening of bottom current transport during the post-LGM deglaciation.

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Early Last Interglacial ocean warming drove substantial ice mass loss from Antarctica

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The future response of the Antarctic ice sheet to rising temperatures remains highly uncertain. A useful period for assessing the sensitivity of Antarctica to warming is the Last Interglacial (LIG) (129 to 116 ky), which experienced warmer polar temperatures and higher global mean sea level (GMSL) (+6 to 11 m) relative to present day. LIG sea level cannot be fully explained by Greenland Ice Sheet melt (~2 m), ocean thermal expansion, and melting mountain glaciers (~1 m), suggesting substantial Antarctic mass loss was initiated by warming of Southern Ocean waters, resulting from a weakening Atlantic me- ridional overturning circulation in response to North Atlantic surface freshening. Here, we report a blue-ice record of ice sheet and environmental change from the Weddell Sea Embayment at the periphery of the marine-based West Antarctic Ice Sheet (WAIS), which is under- lain by major methane hydrate reserves. Constrained by a widespread volcanic horizon and supported by ancient microbial DNA analyses, we provide evidence for substantial mass loss across the Weddell Sea Embayment during the LIG, most likely driven by ocean warming and associated with destabilization of subglacial hydrates. Ice sheet modeling supports this interpretation and suggests that millennial-scale warming of the Southern Ocean could have triggered a multimeter rise in global sea levels. Our data indicate that Antarctica is highly vulnerable to projected increases in ocean temperatures and may drive ice–climate feedbacks that further amplify warming.

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Tracing West Antarctic ice stability in the Amundsen Sea during Late Pleistocene Warm Times

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Marine-based portions of the West Antarctic Ice Sheet (WAIS) hold more than three meters worth of global sea level equivalent ice and are contributing to global sea level rise at an accelerating rate. Yet the fate of Antarctic Ice Sheet remains the largest uncertainty in projections of future sea level rise.

Back in 1978, Mercer suggested a WAIS collapse (i.e. disintegration) as the likely source of ~5m sea level rise during the Eemian, the last interglacial (LIG; ~125,000 years ago), during which peak global temperatures were ~1°C warmer than preindustrial. However, more than 40 years after Mercer's influential paper, we still have not found clear physical evidence for a WAIS collapse during the LIG, or indeed any of the other late Pleistocene interglacials when temperatures were 1-2°C warmer than today.

We here present two new downcore records from the Amundsen Sea off West Antarctica. Geochronological and mineralogical provenance mapping of seafloor surface sediments from the West Antarctic shelf in and around the Amundsen Sea identifies a unique fingerprint of Pine Island (and Thwaites) Glacier. This knowledge is subsequently used to interpret Late Pleistocene down-core records from the continental slope and rise. The most pronounced signal over the past 450,000 years is observed during the LIG and may be taken as indication for detachment of Pine Island Glacier from the bed it rests on today. Our new data are consistent with at least partial WAIS collapse, highlighting the importance of the WAIS in assessing past and future sea level rise.

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Sedimentology and physical properties of marine sediments cores from Port Foster, Deception Island, Maritime Antarctica

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The South Shetland Islands present rapid environmental changes due to regional warming and new climate conditions. Deception Island is situated at the southern end of the South Shetland Islands and is the largest active volcano in Maritime Antarctica. The last subglacial eruptions that occurred in 1969 and 1970 were entirely explosive and affected the mass balance of the local glaciers. Glaciers cover about 57% of the island with a part by pyroclastic materials, and permafrost is present at lower elevations on the island. Over the last century, glaciers have been retreating quickly and the active layer thickness of permafrost is increasing. This study outlines the glacial and climatic processes on the island by sedimentological analysis and physical properties measurements of the superficial marine sediment with an average length of 30 cm. We collected nine samples using a Box-Corer sampler in Port Foster in two expeditions (2014 and 2018). Continuous and non-destructive high-resolution measurements were obtained with the Multi-Sensor Core Logger (MSCL). The physical parameters measured include wet bulk density, magnetic susceptibility, and electrical resistivity. Cores were visually logged and described by sediment colour, grain size, and sedimentary structures. The particle size distribution of sand fractions was obtained by CAMSIZE analyzer, and the silt samples were analyzed by the Malvern laser light scattering granulometer at 1-cm intervals and processed with the Gradistat program . In this work, we will present results from these analyses, with a focus on the reconstruction of sedimentation processes in Deception Island.

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Petrophysical parameters of Central Bransfield Basin marine sediments and their responses to climatic fluctuation

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The work analyzes eight marine sediment cores from the Bransfield Central Basin based on petrophysical parameters in order to investigate lithological, sedimentological and paleoclimatic issues. The water depth varies 304 to 1463 meters of water depth, and core length ranges from 1.5 to 5.2 meters. The cores were submitted to Multisensor Core Logger (MSCL-S), geotechnical tests gamma-spectrometric, granulometric and statistical analyses. Values of density, magnetic susceptibility, electrical resistivity, p-wave velocity, acoustic impedance, porosity, shear strength, total and spectral (U, Th and K) gamma radiation, and grain size were considered. Three distinct lithologies were identified in the Bransfield Central Basin: (a) subglacial deformation till, black colored, gravel content, average density values of 1.902 g/cm3, electrical resistivity of 0.600 Ohm.m, magnetic susceptibility of 497.412 SIx10-5, total gamma radiation of 209.3 nGy/h, and p-wave velocity of 1653,270 m/s; (b) massive diamictons with distinct shades of gray, cobble content, density of 1.475 g/cm3, electrical resistivity of 0.368 Ohm.m, magnetic susceptibility of 237.431 SIx10-5, total gamma radiation of 192.11 nGy/h, and p-wave speed of 1540,061 m/s; (c) siliceous ooze with, olive to brown colored, gravel content, density of 1.146 g/cm3, electrical resistivity of 0.374 Ohm.m, magnetic susceptibility of 4.296 SIx10-5, total gamma radiation 156.3 nGy/h, and p-wave speed 1515.379 m/s. Despite the low accuracy of the estimated date of the sediments, the results can infer climatic oscillations occurring approximately every 500 years. The response of petrophysical parameters is an important tool for separating natural climatic variability from anthropogenic events in cases of potential global warming.

1196

Climate and sea ice reconstructions in the industrial era at the Western Antarctic Peninsula – a multiproxy study based on IPSO25

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Recent changes and variability in climate conditions impact the distribution and properties of sea ice, as it is sensitive to environmental variations. We study the rapidly transforming region of the Western Antarctic Peninsula (WAP) focusing on the conditions and development of sea ice in the pre-satellite era. For this we apply the novel proxy $IPSO_{25}$ (Belt et al., 2016). Three short cores (multicores) from different oceanographic regimes resolve the last 200 years (based on $^{210}Pb_{ex}$ dating) and we analyzed geochemical bulk parameters, biomarkers (highly branched isoprenoids, GDGTs) and diatoms. These results are compared to multiple satellite observations, climate archives and modelled data. This multiproxy-based approach provides insights on changes in spring sea ice cover, primary production regimes, ocean temperature (based on $TEXL_{86}$ and RI-OH) and atmospheric circulation patterns. Despite a good agreement between satellite sea ice cover and the production of the sea ice biomarker $IPSO_{25}$, long-term trends of sea ice decrease at the WAP are not linearly linked to biomarker records. We suggest that masking effects from the complex oceanography and primary production dynamics must be considered in biomarker interpretations for sea ice reconstructions at the WAP. In-phase patterns of the positive Southern Annular Mode and the negative El Niño Southern Oscillation are closely linked to temperature, sea ice distribution, and $IPSO_{25}$ production and could be a key for sea ice reconstructions and projections as well.

Belt et al., 2016. Nature Communications, v. 7, p. 12655.

1479

How quickly can the East Antarctic ice margin complete an advance and retreat cycle?

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The duration of ice advance during Last Glacial Maximum in Antarctica provides insight into its overall sensitivity to environmental thresholds, the response time of the ice sheet to climate and sea level perturbations, and is an essential component in understanding Glacio-Isostatic adjustments and crustal uplift in the present day. While measuring the timing of ice retreat has become relatively routine through the advent of Be -10 exposure dating, determining the onset of glaciation remains difficult due to the challenges of obtaining pre-glacial sediments.

Here, we present a combination approaches to dating the duration of ice extent from Vestfold Hills and Rauer Group in Prydz Bay, including in-situ C-14 in bedrock surfaces, biogenic sediments and subglacial carbonates. These disparate techniques provide a unique insight into the history of ice sheet margin fluctuations in this region. Taken together, they suggest a highly dynamic ice sheet behaviour that is not reflected in existing ice sheet hindcasts, or clearly observed in other parts of the ice sheet margin. We discuss the potential drivers of these short-term fluctuations, and the topographic characteristics of the continental shelf that makes this sector especially prone to these dynamic ice sheet changes.

Regional-scale abrupt Mid-Holocene ice sheet thinning in the western Ross Sea, Antarctica

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Records of ice sheet change from the recent geological past provide insight to the rates, magnitudes, drivers and mechanisms of ice sheet thinning in a future, warming climate. Deglaciation of the western Ross Sea since the last glacial maximum provides a useful analogue for future marine-based ice sheet retreat, but existing empirical and model data do not provide a coherent history of ice loss over this time. We present a cosmogenic surface-exposure chronology from Mawson Glacier. Our data record at least 220 m of abrupt ice thinning at 7.5–4.5 kya (occurring at a rate of 10–397 cm yr-1, 2 σ), followed by more gradual thinning until the modern glacier geometry was reached within the last thousand years or so. The timing, rates and magnitudes of thinning at Mawson Glacier are remarkably similar to that documented 100 km to the south at Mackay Glacier. Together, both outlet glaciers demonstrate that abrupt regional-scale deglaciation occurred in the western Ross Sea in the Mid-Holocene. Once initiated, ice sheet thinning occurred in this region at rates similar to some rapidly changing parts of Antarctica today and persisted for approximately 570–720 years. Ocean thermal forcing likely drove grounding-line retreat and ice drawdown, which then accelerated as a result of marine ice sheet instability as these glaciers retreated into overdeepened basins in the western Ross Sea.

1461

Greenhouse to Icehouse Antarctic paleoclimate and ice history from George V Land and Adélie Land shelf sediments: IODP mission-specific-platform Expedition 373

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The George V and Adélie Land continental shelf of East Antarctica contains a record of Antarctica's climate and ice history from the warm and vegetated landscapes of Eocene greenhouse climates through latest Eocene glacial inception to today's ice-covered continent. Because Paleogene to Pleistocene seaward-dipping strata are accessible at shallow depths under the sea bed, we can access them with robotic seafloor drills such as MeBo. IODP Expedition 373 plans to carry out this drilling, but is currently postponed until 2023 or later.

The history of this Antarctic margin includes warm-world high-CO_2 environments, which will help understand Antarctic climate and the limits of ice-sheet stability under conditions expected from global warming. In particular, we plan to investigate:

- Antarctica's climate during Early/Middle Eocene greenhouse warmth, including cyclicity, temperatures, and vegetation. We would provide high latitude temperatures address the pole-equator gradient and we will look for evidence for DeConto's permafrost hypothesis for hyperthermals;
- Climate cooling over the late Eocene in advance of main glacial inception. Were there precursor glaciations? What conditions led to Antarctica becoming the ice-covered continent we see today? Up to now there are extremely few well-recovered late Eocene sediment sequences from Antarctica, and we can fill this knowledge gap;
- The timing, environmental conditions, and extent of major ice advance at the Eocene/Oligocene boundary (~34 Ma), and the role of glacial isostatic adjustment (GIA) – e.g., relative sea level rise adjacent to expanding ice sheets;
- Oligocene ice and climate conditions, which are only poorly known.

1343

IODP Expedition 382 (Iceberg Alley) – Preliminary Results

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International Ocean Discovery Program (IODP) Expedition 382, Iceberg Alley and Subantarctic Ice and Ocean Dynamics, sailed in early 2019 to: 1. investigate the long-term history of the Antarctic Ice Sheet (AIS) and how ice retreat responded and contributed to global sea-level; 2. decipher how past changes in ocean bioproductivity, sea ice extent, and dust deposition in the Southern Ocean might have influenced atmospheric CO_2 variability.
Located in the southern Scotia Sea, Iceberg Alley is the path where many Antarctic icebergs drift north into the warmer waters of the Antarctic Circumpolar Current (ACC). We drilled biosilica-rich sediments at three sites (U1536, U1537, U1538) continuously back to 3.5 Ma. The patterns in the magnetic susceptibility record correlate closely to the 800 kyr dust record in the EDC ice core, which provides both millennial-resolution dating and a record of Southern Ocean westerly winds. Magneto-, bio-, and cyclo-stratigraphy extends the dating to the older part of the record, covering key time periods in AIS evolution such as the mid-Pliocene warm period, the mid-Pleistocene transition, and interglacials and glacial terminations of the last 800 kyr. High concentrations of iceberg-rafted debris (IBRD) signal ice margin retreat, and geochemically-determined provenance of the IBRD will fingerprint sources of icebergs and regional ice retreat. The resolution of the dating will allow us to evaluate leads and lags between dust deposition, sea ice extent, and sea surface temperature, and interpret them in terms of global climate and atmospheric CO_2.

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Glacier retreat history of the Crystal Sound in the Antarctic Peninsula

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The three gravitational cores (BS17-GC16, -GC17 and -GC18) were obtained from the deep basin of the Crystal Sound of the Antarctic Peninsula in 2017. Paleoenvironmental interpretations are based upon TOC, opal, TN, chloride/sulfate ions, diatom assemblage, particle size, sedimentary structures, and physical properties. Chronology is constrained by 25 AIO 14C dates including ramped PyrOx 14C dating in the lower section of the longer core BS17-GC18 (8.9 m). The calibrated bottom age is ~11.4 cal. kyr BP that corresponds to the timing of early Holocene climatic optimum (HCO) in the AP. We recognize two climatic events: the middle HCO (~9.0 to ~3.0 cal. kyr BP) and the Neoglacial (~3.0 cal. kyr BP to modern). The 2.2-m-thick turbidite layer in the lower section of the core is the result of a high energy transport system to the deep basin within the crystal sound. During the period from the early HCO to ~9.0 cal. kyr BP, the slight increase of marine diatoms and opal contents indicates the continued seawater intrusion from open ocean under a retreating ice shelf. The low chloride/sulfate pore water concentrations prior to the middle HCO suggest deposition in brackish environments associated with grounding zone proximal lithofacies. During the middle HCO, the elevated contents of TN, TOC and opal is accompanied by high diatom valve abundance in response to enhanced phytoplankton production facilitated by open ocean environment. The decline of TN, TOC, opal and diatom valves around ~3.0 cal. kyr BP corresponds to the Neoglacial climatic event.

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Antarctic Science - Global Connections

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SESSION 15

ICE SHEET-SOLID EARTH INTERACTIONS: GIA, LANDSCAPE EVOLUTION AND GEOTHERMAL HEAT FLUX

INTERNATIONAL SCIENCE COUNCIL
SCAR
SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

Erik Ivins, Stewart Jamieson, Alex Burton-Johnson
Ricarda Dziadek, Jennifer Taylor

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Geothermal heat flow in Antarctica: current and future directions

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This presentation introduces the different methods applied to derive Antarctic geothermal heat flow (GHF), their advantages and limitations, and recommendations for future directions.

Antarctic GHF affects the temperature of the ice sheet, determining its ability to slide and internally deform, as well as the behaviour of the continental crust. However, GHF remains poorly constrained, with few and sparse local, borehole-derived estimates, and large discrepancies in the magnitude and distribution of existing continent-scale estimates from geophysical models. We review the methods to extract GHF, present a compilation of borehole and probe-derived estimates from measured temperature profiles, and recommend the following future directions: 1) Obtain more borehole-derived estimates from the subglacial bedrock and englacial temperature profiles. 2) Estimate GHF beneath the interior of the East Antarctic Ice Sheet (the region most sensitive to GHF variation) via long-wavelength microwave emissivity. 3) Estimate GHF from inverse glaciological modelling, constrained by evidence for basal melting. 4) Revise geophysically-derived GHF estimates using a combination of Curie depth, seismic, and thermal isostasy models. 5) Integrate in these geophysical approaches a more accurate model of the structure and distribution of heat production elements within the crust, and considering heterogeneities in the underlying mantle. And 6) continue international interdisciplinary communication and data access.

Associated Paper:

Burton-Johnson, A., Dziadek, R. & Martin, C. (2020). Geothermal heat flow in Antarctica: current and future directions. The Cryosphere Discussions.

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Re-evaluating the elastic response to ice mass change in Antarctica

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Present-day mass loss across Antarctica evokes an instantaneous, elastic deformational response of the solid Earth. In regions such as the northern Antarctic Peninsula and the Amundsen Sea Embayment, elastic uplift rates at GNSS sites reach up to 7-10 mm/yr, or up to~30-45% of the observed uplift rate. In glacial isostatic adjustment (GIA) studies, this elastic response is often modeled and removed from the observed deformation, and the viscous component, inferred to be the residual deformation, is used for constraining mantle viscosity. Because the inferred viscous deformation depends on the accurate modelling of the elastic component, biases and uncertainties in the latter directly impact conclusions on the mantle's rheology. Often elastic deformation is modeled using a 1D Earth with parameters defined by a seismic velocity model, typically a globally averaged reference such as PREM or STW05. Regional differences from the global reference and 3D departures from the 1D profile result in biases and uncertainties in the modeled deformation that remain poorly understood. Additionally, coarse ice-load grids often used for modelling Antarctic-wide elastic deformation may not resolve changes of some rapidly changing glaciers and ice streams, potentially resulting in under predictions of elastic deformation rates. We quantify these uncertainties and their impact on GIA studies using an ensemble of 1D elastic structures sampled from density and seismic velocity models of Antarctica's crust and upper mantle with a combination of 10km resolution continent-wide ice mass balance estimates and new, high resolution ice mass balance estimates of the Amundsen Sea region.

1366

Magnetic and gravity views reveal intra-crustal heterogeneity in the Wilkes Subglacial Basin of East Antarctica

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The Wilkes Subglacial Basin (WSB) is a major intraplate tectonic feature in East Antarctica. Recent modelling of its subice topography lends support to a long-standing hypothesis predicting that the wide basin is linked to flexure of Precambrian cratonic lithosphere induced by the Cenozoic uplift of the adjacent Trasantarctic Mountains. However, potential field and radar exploration suggest that its narrower structurally controlled sub-basins may have formed in response to more localised Mesozoic to Cenozoic extension and transtension and superimposed Cenozoic glacial erosion.

Here we exploit new enhanced aerogeophysical and satellite gravity gradient imaging to reveal the 4D heterogeneity in the crust beneath the WSB. By stripping out the effects of crustal and lithosphere thickness variations we obtain residual intra-crustal gravity anomalies that are compared with enhanced aeromagnetic anomaly images. Depth to magnetic and gravity source estimates help constrain the first combined 2D magnetic and gravity models for the WSB.

Our first model reveals the lithospheric scale boundary along the eastern margin of the northern WSB that separates the Cambro-Ordovician Ross Orogen from an inferred Precambrian Wilkes Terrane. Further south the Precambrian basement appears to be both shallower and more felsic.

We conclude that these first order differences in basement depth, bulk composition and thickness of metasediment/sediment cover are likely to also affect geothermal heat flux variability beneath different sectors of the WSB, with potential cascading effects on subglacial hydrology and East Antarctic Ice Sheet flow.

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4D Antarctica: a new effort aims to help bridge the gap between Antarctic crust and lithosphere structure and geothermal heat flux

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Seismology, satellite-magnetic and aeromagnetic data, and sparse MT provide the only available geophysical proxies for large parts of Antarctica's Geothermal Heat Flux (GHF) due to the sparseness of direct measurements. However, these geophysical methods have yielded significantly different GHF estimates. This restricts our knowledge of Antarctica's contrasting tectono-thermal provinces and their influence on subglacial hydrology and ice sheet dynamics.

For example, some models derived from aeromagnetic data predict remarkably high GHF in the interior of the West Antarctic Rift System (WARS), while other satellite magnetic and seismological models favour instead a significantly colder rift interior but higher GHF stretching from the Marie Byrd Land dome towards the Antarctic Peninsula, and beneath parts of the Transantarctic Mountains. Reconciling these differences in West Antarctica is imperative to better comprehend the degree to which the WARS influences the West Antarctic Ice Sheet, including thermal influences on GIA. Equally important, is quantifying geothermal heat flux variability in the generally colder but composite East Antarctic craton, especially beneath its giant marine-based basins.

Here we present a new ESA project- 4D Antarctica that aims to better connect international Antarctic crust and lithosphere studies with GHF, and assess its influence on subglacial hydrology by analysing and modelling recent satellite and airborne geophysical datasets. The state of the art, hypotheses to test, and methodological approaches for five key study areas, including the Amundsen Sea Embayment, the Wilkes Subglacial Basin and the Totten catchment, the Recovery and Pensacola-Pole Basins and the Gamburtsev Sublgacial Mountains/East Antarctic Rift System are highlighted.

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Temporal and environmental constraints on the eruption history of Gaussberg Volcano

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Subglacial volcanic eruptions can have significant impact on ice sheet behavior and/or volume via short-term melting of ice and longer time-scale effects on regional geothermal heat flow, surface uplift and subsidence through time. Gaussberg volcano, located on the coast of East Antarctica at 89°19’E is an ice-free, glacially eroded, pillow-dominated, cone-shaped edifice that rises 370 m absl. Gaussberg volcano is the only confirmed volcano within this sector. Gaussberg volcano is suspected to have erupted entirely beneath ice.

Past research has focused on determining magma source and genesis. The timescale of volcanism is uncertain as a broad range of ages for the lavas (~56 ka, 9 Ma and 20 Ma) have been produced by K/Ar isotopic techniques. It is also unclear if Gaussberg is one edifice or an edifice that has been constructed within the remnants of earlier eruptive phases.

In this study we aim to constrain the age and environment of eruption of Gaussberg volcano using legacy samples originally collected by Sheraton and Ellis (ANARE 1977). The samples are ultrapotassic (11.7-12.1 K2O%) olivine-bearing lamproite lavas mainly comprising leucite, clinopyroxene and glass. We provide a new chronology of eruption using 40Ar/39Ar technique applied to leucite (20.5-21.7 wt% K2O). The volatile contents (H2O) of volcanic glass measured with Fourier-transform infrared spectroscopy will constrain the quench pressures of lavas and hence the thickness of overlying ice at time of eruption. We expect these new constraints on phases of volcano growth and paleoenvironment can inform Antarctic heat flow and ice sheet models.

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Absolute gravity measurements at Jang Bogo station and Mario Zucchelli station in Antarctica

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Using the FG5#210, we have conducted absolute gravity measurements at Jang Bogo station and Mario Zucchelli station in Terra Nova Bay. Jang Bogo station is a South Korean Antarctic research station which has been operated since 2014. There is a gravity point named JBSAG1 and we conducted the measurements at JBSAG1 from 17 to 24 November 2019. Since the JBSAG1 is located at the bottom of the narrow maintenance bay with the depth of about 1 meter, the vertical gravity gradient at the point is not linear w.r.t the height. This may cause additional errors for the comparison of the gravity values obtained by different types of gravimeters. We thus established another gravity point named JBSAG2 on the flat floor near JBSAG1 and conducted the measurements from 25 to 27 November. The precisions of these measurements were better than 0.4 micro gals.
In Mario Zucchelli station, there are two gravity points named TNB AB and IAGS where absolute gravity measurements have been repeatedly conducted thus far. We conducted the measurements at TNB AB from 30 November to 2 December, and from 3 to 5 December at IAGS. The measurements at both points were conducted with the measurement precision of less than 0.4 micro gals.
In this presentation, we report the outline of the measurements and the preliminary results.
This study was partially supported by JSPS KAKENHI Grant No. 17H06321.

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Antarctic Ice Sheet stability and its sensitivity to evolving bedrock topography and climate forcing

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Reproducing the large-scale oscillations in Antarctic ice volume that have been interpreted from ocean sediment cores has long proved challenging for ice sheet modelling studies. This is due to strong stabilising climate feedbacks following the growth of a continental sized ice sheet. Recent work to resolve this model-data disagreement has focused on the marine-based sectors of the ice sheet, which are vulnerable to marine ice sheet instabilities and potentially the recently proposed marine ice cliff instability. However, the larger scale changes in the Oligocene and Miocene (with some estimates of oscillations equivalent to 85–110% of the modern-day ice volume), requires substantial loss of terrestrially-based Antarctic ice. Additionally, recent reconstructions of the Antarctic bedrock topography suggest that the marine-sectors of Antarctica were less extensive in the past. This also supports a greater role for retreat of the terrestrially-based Antarctic Ice Sheet in the past. Here we explore how changes in bedrock topography affect ice sheet stability. We also explore how recent climate model simulations that have a greater polar amplification than earlier models affect the ability to simulate Antarctic Ice Sheet change consistent with the geological records.

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Thermal structure and heat flux of the Antarctic lithosphere

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Geothermal heat flux strongly influences ice temperature, viscosity and water content, as well as basal melting, which in turn determines the deformation response of ice under stresses applied by the overlying ice column. Therefore, high quality maps of geothermal heat flux are crucial when monitoring ice dynamics, shape and mass balance of the Antarctic Ice Sheet. Since direct measurements are sparse because of the large ice thicknesses, other solid earth models are necessary to estimate the heat flux. We determine the geothermal heat flux over the Antarctic continent based on a 3D thermal model of the lithosphere, obtained from seismic tomography using a mineral physics approach, and corrected for compositional changes through a joint inversion with gravity data in an iterative scheme. Since this model only provides reliable relative temperature variations but is somewhat biased in the absolute values, we calibrate it using standard geotherms for well-studied cratons for each depth layer, taking into account the non-linear relationship between velocity and temperature. The resulting model provides accurate temperature variations as well as consistent absolute temperatures within each layer. The lower boundary of the thermal lithosphere, defined here as the 1300°C isotherm, is found to lie around 100km in West Antarctica while extending down to almost 300km in East Antarctica. The resulting lithospheric heat flow also shows a clear distinction between East and West Antarctica with locally elevated fluxes in the Antarctic Peninsula and beneath the Ross Ice Shelf.

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Introducing "PetroChron Antarctica": A new geological database for interdisciplinary use

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It is increasingly clear that the Antarctic lithosphere has complex interactions with the oceans and cryosphere. A deeper understanding of these interactions depends on the ability to integrate large multidisciplinary datasets. However, global geological datasets are commonly discipline-specific, and Antarctic datasets are poorly represented.

We introduce a new relational database “PetroChron Antarctica” housing both geochemical and geochronology datasets from geological samples across Antarctica (south of 60°). Data are sourced from various existing databases (e.g. GEOROC, DateView, Petlab) and more than 350 individual publications. Also included are a range of geochemical indices, naming schema, and physical property estimates. Information is compiled in a standardised format for reliability and comparability. To increase filtering capability, this database has a relational structure containing numerous sub-tables adapted from the recently released global geochemical database (Gard, M., Hasterok, D., Halpin, J.A., 2019. Global whole-rock geochemical database compilation. Earth Syst. Sci. Data 11, 1553-1566.).

PetroChron Antarctica is an open-access public database. Data can be displayed and explored using the ESRI Online Web Feature Service, and can be readily integrated with other Antarctic geological and geophysical datasets (e.g. GeoMAP). Datasets will be available for download in a .csv format, but exist in a structure format acceptable for database management systems (e.g. SQL).

We hope that PetroChron Antarctica will lead to new understandings in the Antarctic geosciences (e.g., tectonic evolution, heat flow, landscape evolution) and have application across other scientific fields (e.g., ice sheet history, soil chemistry, biodiversity). We encourage contributions and feedback from the Antarctic community.

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Geothermal Heat Flux estimates from Thermal Isostasy

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Geothermal heat flux (GHF) is a necessary boundary condition for developing accurate dynamic glacial models, but GHF is poorly constrained. GHF estimates from seismic and magnetic-based methods show poor correlation to each other and to GHF constraints provided by observations on conjugate margins. This poor performance is likely due to the large uncertainties in thermophysical properties of the crust, particularly radiogenic heat production. The thermal buoyancy responds to the integrated thermal state of the lithosphere, expressing variations through differences in elevation, thereby providing an independent estimate of GHF. To obtain GHF from thermal isostatic calculations, we use Monte Carlo methods to fit elevation, seismic velocity estimates of mantle temperature and magnetic-based Curie depth estimates. This method requires input estimates of crustal thermophysical properties, which we predict using new empirical correlations to seismic velocity and density. These empirical models are developed from global and regional analyses of whole rock geochemistry and laboratory measurements and/or thermodynamic calculations of physical properties. Geochemical data from exposures of Antarctic terranes and conjugate margins are used to calibrate a priori heat production distributions and are key to producing more accurate models of lithospheric temperatures and GHF.

1026

Effects of Local Snowpack on geodetic observation at Syowa Station with UAV survey

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Syowa Station, located in East Ongul Island, East Antarctica, has three different space geodetic observation facilities (GNSS, DORIS, and VLBI) and a superconducting gravimeter. These geodetic observations are expected to capture the glacial isostatic adjustment (GIA) effect caused by the melting of the Antarctic ice sheet since the last glacial maximum. However, it is necessary to remove the effects of local snowpack close to the observation sites for detecting the GIA signal precisely from these geodetic observations.
In this study, we derived the detailed snowpack distribution in Syowa Station from unmanned aerial vehicle (UAV) photographic survey, and evaluated the effects of snow mass on those geodetic solutions: elastic deformation, and gravitational attraction.
We conducted the aerial photographs taken by UAV, “senseFly eBee Plus” and “DJI Inspire 2”, around once a month during the 59th Japanese Antarctic Research Expedition (JARE59) activity (2017-2019).
The digital elevation models (DEM) and the orthomosaic images were generated from the aerial photographs with the SfM software “Pix4Dmapper.” Then, the time-series of snowpack distribution in the survey area was extracted from changes in DEMs. In this presentation, we show the details of observed changes in the snowpack depth distributions, and discuss the comparison between the estimated elastic deformation and gravity effect of local snow accumulation and the geodetic solution derived from each geodetic facility.

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Instantaneous Slow Cooling of the Transantarctic Mountains

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Thermochronologic data collected along the Byrd Glacier Outlet of the Transantarctic Mountains (TAM) reveals a prolonged and punctuated denudational history.

Samples collected along two vertical transects, each with over 1000 m of vertical relief, separated by ~30 km, all have apatite fission track (AFT) cooling ages of ~80 Ma. The >1 km of relief with nearly identical cooling ages indicates rapid denudation associated with significant topography. The spatial extent of this rapid cooling indicates that this topography was of regional importance. These thick sections of crust with similar AFT ages suggest rapid cooling at ~80 Ma as up to 1.5 km of crust cooled below ~120° C.

In contrast, evaluation of the track lengths to estimate the thermal histories of the samples indicates long-term, slow cooling, of the crust, with all samples spending an extended period of time (10s of millions of years) within the partial annealing zone (PAZ: 120°C to 60°C). This instantaneous, but slow, cooling cannot be explained by regional erosion (vertical conduction).

However, this instantaneous slow cooling can be explained by incision of a deep gorge adjacent to the samples (dominated by horizontal conduction). Numerical simulations indicate that rapid incision of a gorge followed by slow regional erosion can result in >1 km of crust rapidly passing through the AFT closure temperature (~120°C), and then remaining in the PAZ for an extended time (10s of millions of years). This scenario of deep incision results in simultaneous, but relatively slow, cooling of the crust by horizontal conduction.

1704

Quantification of the Uncertainty in Retrieving Antarctic Mantle Rheology: Toward Systematic Intercomparison

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Modeling mantle viscous response to past ice sheet change is crucial to correcting space-based data (gravity and altimetry) to determine Antarctic ice mass balance. Terrestrial GPS stations, operating for more than a decade, do provide some GIA information about viscous response. While this information is spatially sparse, the station data has none-the-less helped to determine that West Antarctic mantle viscosity and lithospheric structure significantly deviate from those of Canada and Fennoscandia, places where mantle viscosity is fairly rigorously constrained. New seismic mapping by Lloyd et al [2020] using adjoint waveform inversion (ANT-20), reveal great heterogeneity in the Voigt averaged S-wave velocity down to 1000 km depth. Here we connect S-wave mapping to 3 different scaling relationships to mantle viscosity. We assume both S-wave velocity and mantle strength are related to local temperature, $T0(r) + \delta T (r, \theta, \phi)$, where $T0(r)$ is the spherically averaged value at radius, r, and $\delta T (r, \theta, \phi)$ is the local deviation from the spherical average. Resultant viscosity maps from the different scaling relations may then be intercompared. There is uncertainty in each scaling relationship. Each of the relations must correct for a temperature-dependent anelastic slowing of the S-waves that is not directly related to the wave slowing effects of thermal expansion [Karato 2008]. Assessment of this intercomparison is presented here and we discuss our progress in quantifying the uncertainty in bounding, the effective mantle viscosity down to 1000 km beneath the Antarctic continent.

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Investigating Eocene-Oligocene alpine glacier flow and erosion over the Gamburtsev Subglacial Mountains, East Antarctica using a numerical ice flow model.

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The Gamburtsev Subglacial Mountains (GSM) represent one of the nucleation sites of the East Antarctic Ice Sheet at the Eocene-Oligocene Transition (EOT). The mountains have an alpine morphology representing erosion under valley-constrained glaciers or a regional ice cap, the survival of which reflects long-term protection under cold-based, non-erosive. In the landscape are cirques and hanging valleys positioned above glacially overdeepened trunk valleys that radiate out from the mountain range. The overdeepenings and the elevations of the cirque floors are proposed to be co-located with the palaeo-ELA of these glaciers. Although it has been assumed that this ice reflected the climate at the EOT, there may have been glaciers on Antarctica at various stages since the Late Cretaceous. This brings into question the age of the glacial signal recorded in the GSM. Here I use a numerical glacier model (PISM) run at high-resolution and under a climate that cools gradually to understand the likely ice flow patterns and basal thermal regime of small-scale glaciation and the early icecap on the GSM. We also suggest potential erosion patterns, determined using a range of velocity to erosion rate relationships, that may have been experienced over the mountain range. In doing so we thereby hypothesise the length of time over which erosive glacial conditions persisted in order to overdeepen the GSM. Finally, I discuss the climate conditions under which these glaciers grew and consider whether the glacial landscape of the GSM was carved at the EOT or under earlier, warmer, conditions.

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Subglacial character of the Aurora Basin, East Antarctica, from novel seismic waveform modelling

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Rising sea levels present a serious and increasing threat to a large percentage of the global population. Whilst scientific focus has concentrated on the rapidly retreating West Antarctic ice sheet, East Antarctic ice sheets have the capability to dominate future contributions to sea level rise and there is evidence for a history of partial collapse. The character of the ice sheet – bedrock interface of the Wilkes and Aurora Basins, which underlie a significant proportion of the East Antarctic ice sheet, may have a substantial impact on ice sheet instability. Seismological methods are well established in their ability to infer detail in subsurface layers, and novel passive methods offer the potential to highlight hidden changes in the ice-rock structure through the variation of ambient signals passing through the basal layers. This research focuses on utilising these seismic techniques to generate a comprehensive basis of the Aurora Basin, with particular interest in the nature and thickness of sediment in the ice sheet – bedrock interface zone and whether this layer is saturated or frozen, with the long-term aim of providing early warning of ice sheet degradation. We apply newly developed computational tools in seismic waveform simulation, and a detailed compilation and analysis of existing geophysical data to determine the present framework of knowledge regarding the Aurora Basin and Totten Glacier. This study will also incorporate regional modelling of ice-atmosphere and ice-ocean interactions and consideration of surface and subglacial hydrology in order to provide a more complete understanding of present basal conditions.

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New geodetic constraints on GIA and elastic deformation in East Antarctica

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Geodetic observations of East Antarctic bedrock deformation are sparse, with sometimes more than 1000 km between GPS sites. We present initial results from a new network of six continuous GPS sites in the region 80-120° east (from Davis Station to beyond Totten Glacier). We also substantially extend the existing record at Bunger Hills. Forward and inverse models of present-day bedrock deformation due to GIA disagree substantially in this region. We compare the GPS-derived site velocities, including both horizontal and vertical velocities, with a range of forward and inverse GIA models and discuss potential elastic effects and the implication for the accuracy of GIA models in this region.

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Improved GPS bedrock time series in Antarctica considering observation-level signal-to-noise ratio data

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Many GPS bedrock coordinate time series from Antarctica are badly affected by large, transient artefacts that are especially evident in the horizontal coordinate components, but in some cases show impact on the vertical coordinates. It has been suggested that these are a result of build up of snow and ice within "choke ring" antennas that form the majority of sites within Antarctica. Treatment of these transient data has thus far focused on removing them via manual and hence subjective data editing. We investigate the observation-level signal-to-noise ratio (SNR) data recorded by modern GPS receivers, and first explore their usefulness for robust data editing. We show that the standard deviation of SNR time series in elevation bands shows substantial variation which correlates with the transient coordinate signals and that SNR-based editing is a robust and repeatable data editing approach that is useful in the analysis of Antarctic time series. We then attempt to improve the coordinate time series themselves by applying SNR-based observation weighting in the original GPS data analysis. We illustrate these methods on velocities estimated from time series from long-running sites within the ANET network of West Antarctica.

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A New Geothermal Heat Flux Model of Antarctica with Machine Learning

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Understanding the geothermal heat flux in Antarctica is crucial for ice sheet modelling and glacial isostatic adjustment. It affects the ice rheology and can lead to basal melting, thereby promoting ice flow. Direct estimates are sparse and models inferred from e.g. magnetic or seismological data differ immensely. While these different approaches are generally justified, they go along with strong simplifications and great uncertainties.
To overcome such shortcomings and assuming that heat flux is substantially related to its geodynamic setting, we adopt a machine learning approach. More specifically, we establish a Gradient Boosted Regression Tree model, in order to find an optimal predictor for locations with sparse direct heat flux estimates. With this technique, a complex relationship between geothermal heat flux and relevant geophysical features (e.g. gravity field, magnetic anomaly, crustal and lithospheric thickness) is generated. Thereupon, we can produce a map of predicted heat flux beneath the Antarctic ice sheet.
However, this approach largely relies on global data sets, which are notoriously unreliable in Antarctica. Therefore, validity and quality of the data sets is reviewed and discussed. Using regional and more detailed data sets of Antarctica's tectonic neighbors improves the predictions. The performance of the machine learning algorithm is explored by comparing the predictions to the existing estimates. Finally, we present a new geothermal heat flux model and discuss differences to previous predictions.

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Uppermost mantle structure beneath the Amundsen Sea Embayment, West Antarctica

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Knowledge of the uppermost mantle seismic velocity structure beneath the Amundsen Sea Embayment (ASE), West Antarctica is important for understanding the structure and tectonic evolution of the region, as well as for constraining the interactions between the solid Earth and the cryosphere. In this study, we investigate the uppermost mantle seismic structure beneath Thwaites Glacier and Pine Island Glacier using travel times from ~100 small (0.6 < ML < 3.2) seismic events (most likely glacial in origin) occurring from 2015-2017. Using seismic data collected by the Polar Earth Observing Network (POLENET/A-NET) and the UK Antarctic Network (UKANET), our tomographic inversion constrains uppermost mantle P-wave velocities (VPn). The results show variable uppermost mantle structure beneath Thwaites Glacier and Pine Island Glacier, with Pn velocities varying from ~8.15 km/s to ~8.35 km/s. We image lower Pn velocities beneath Pine Island Glacier, consistent with previous evidence suggestive of rifting. Beneath Thwaites Glacier, we image higher velocities. With variations in uppermost mantle seismic velocities being dependent on physical properties, such as temperature, composition, and grain size, it is evident that the ASE lithosphere should be considered laterally variable. Current glacial isostatic adjustment (GIA) models of the ASE assume a spatially homogeneous, elastic lithosphere (Barletta et al., 2018); however, in order to accurately capture short wavelength GIA signals, incorporating a laterally variable lithosphere may prove essential (Nield et al., 2018).

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Mantle xenoliths help constrain a 3-dimensional viscosity mantle map of Antarctica for better glacial isostatic adjustment (GIA) and heat flow modelling

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Several estimates for the Antarctic ice sheet contribution to sea level rise rely on modelling basal heatflow and the solid Earth response to changes in ice and water loading, known as glacial isostatic adjustment. Predicting this adjustment utilises ice sheet history and Earth models, which are exceptionally difficult to constrain for a continent under ice and require a multi-disclipinary approach. Mantle petrology and geochemistry studies can help and are an underutilised discipline for constraining Earth rheology in Antarctica. It studies, amongst other things, 'mantle xenoliths' which are fragments of lithospheric mantle rock brought to the surface by volcanic eruption. Mantle xenoliths can be studied to quantify properties including water content, grain size, chemistry (CFMAS), temperature and pressure. Over 100 years of mantle xenolith research has shown there is significant lateral variation in mantle properties between East and West Antarctica, and within West Antarctica. For example, between northern Victoria Land, southern Victoria Land and Marie Byrd Land there are differences in geothermobarometry, lithospheric geotherms and mantle water contents. Lithospheric mantle temperatures can be calculated from mantle xenoliths, including Cenozoic changes to heatflow in the Victoria Land portion of the West Antarctic rift system. Synthesis of the properties of the mantle from the study of mantle xenoliths can be reconciled with mantle properties determined by geophysical and remotely sensed methods to map in much finer, and geologically constrained, detail lateral and vertical variations in mantle properties to obtain better accuracy for glacial isostatic adjustment models and for basal heatflow models.

1060

Subglacial hydrology in the Ellsworth Subglacial Highlands and its evolution over the last 150 kyrs

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Subglacial water located at the onset of the ice streams has the potential to enhance ice flow downstream by lubricating the ice-bed interface. There are more than 400 subglacial lakes across Antarctica, of which 20% are in West Antarctica and the connections between these subglacial lakes is fundamental to understanding past and present ice sheet flow. We have recently demonstrated the presence of more than 30 subglacial lakes located in the Ellsworth Subglacial Highlands (ESH) near the Pine Island/Rutford/Institute ice divide and we aim to understand the connections between these under a range of ice sheet configurations. We characterize the present configuration of the drainage system and the connection of the subglacial lakes based on a new bed DEM of the region. We then use existing ice sheet model output that reconstructs the geometry of the ice sheet over the last 150 ka to understand the evolution of the subglacial hydrological system and find that >20 subglacial lakes have remained underneath the ice since the Last Interglacial. We show that a number of lakes are sensitive to small changes in the position of the ice divide between the Amundsen and Weddell Sea regions, and thus that these may have switched drainage direction under more restricted ice sheet configurations. Additionally, some lakes are connected in chains, and remain-so as the ice sheet evolves. The pathways of drainage from these lakes is linked to the hydrological network of the main WAIS ice streams, with particular concentrations of flow towards the Thwaites Glacier.

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Geodetic Measurements of GIA at Aboa, Vestfjella mountains, Western Dronning Maud Land

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Repeated absolute gravity measurements when used together with vertical rates from, e.g., GPS bring multiple benefits to geodynamical research. Gravity rates can be used to control observed vertical rates and predictions from GIA models. Plotting gravity rates versus vertical rates at a number of stations provides a slope that gives information on the mechanism behind the vertical rates (e.g., GIA) and an intercept that can be used to control the reference frame of the vertical rates. Absolute -gravity stations are an important part of the geodetic infrastructure of the Antarctic.

The Finnish Geospatial Research Institute (FGI) has occupied the absolute gravity station at the Finnish Antarctic Research Station Aboa (Western Dronning Maud Land) seven times since 1993. The permanent GPS station at Aboa was established in 2003 and has been in constant operation since.

Here we present latest results from geodetic measurements at the Aboa Station. The time series of absolute gravity is corrected for changes insnow and ice masses in the immediate proximity of the gravity station. The gravity time series is then compared with regional gravity change from the GRACE satellite: both indicate an increasing trend in gravity since around 2005. We have also performed a detailed PPP calculation of the Aboa GPS time series. It shows a moderate land uplift, in apparent contradiction with the gravity increase. The explanation appears to be that the direct attraction of the increasing regional snow mass, not the vertical motion, is the dominant effect in the absolute-gravity time series.

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Constraining upper mantle viscosity from post-seismic deformation in the Northern Antarctic Peninsula following the 2013 magnitude 7.7 Scotia Sea earthquake

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Large earthquakes in the vicinity of Antarctica have the potential to cause post-seismic viscoelastic deformation on the continent, affecting measurements of displacement that are used to constrain models of glacial isostatic adjustment (GIA). In November 2013 a magnitude 7.7 strike-slip earthquake occurred in the Scotia Sea around 650 km from the northern tip of the Antarctic Peninsula. GPS coordinate time series from the Peninsula region show a change in rate after this event indicating a far-field post-seismic viscoelastic deformation signal is present. We use a global spherical finite element model to investigate the extent of post-seismic viscoelastic deformation in the northern Antarctic Peninsula. We investigate possible 1D earth models that can fit the GPS data and consider the effect of including a simple 3D earth structure in the region. These results can provide independent constraints on likely earth structure which is useful for studies of GIA and consideration of solid-earth feedbacks on ice-sheet evolution.

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Can a GIA model with lateral variations in Earth structure explain GPS displacement rates in the Southern Antarctic Peninsula?

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The one-dimensional, radially varying Earth structure adopted in many glacial isostatic adjustment (GIA) models leads to bias in model-predicted uplift rates in locations where rheological parameters differ significantly from the globally averaged 1D structure used. To overcome this problem, regional studies of GIA often make use of a 1D Earth structure that is representative of local parameters, for example to capture the low viscosity upper mantle in West Antarctica, although it remains unclear over what spatial scale the 1D Earth structure may be relevant. In the Southern Antarctic Peninsula GPS uplift rates reveal significant variability over short spatial scales, with differences of up to 5.8 mm/yr observed over a distance of only 500 km, which cannot be replicated using a GIA model that adopts a 1D regional Earth structure. Here we use a finite element GIA model that includes 3D Earth structure derived from a high resolution seismic velocity model to investigate whether lateral variations in lithospheric thickness and upper mantle viscosity can explain this small scale variability in uplift rates. Combining the 3D GIA model with an ice history that includes Late Holocene changes improves the fit to GPS observations in the Southern Antarctic Peninsula.

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GIA modeling of geodetic signals in East Antarctica for constraining the recent mass balance and the last deglaciation history

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Time series of gravity changes by GRACE, which launched in 2002, described in detail the movement and change of mass in Antarctica. However, the observation of gravity fields such as GRACE includes not only the change of ice mass but also the change of mass caused by the deformation of the solid Earth called Glacial Isostatic Adjustment (GIA). For this reason, an accurate estimate of the solid Earth deformation is required to prescribe the recent ice mass balance by gravity observations.
Furthermore, the current deformation rate of the solid Earth also includes the component induced by the melting of the Antarctic Ice Sheet (AIS) since the Last Glacial Maximum. Therefore, the estimates of the deglaciation history of the AIS on a time scale over 10,000 years derived from geomorphic and geological observations are also required. At present, several scenarios of the AIS deglaciation history based on geomorphic and geological data have been proposed and are still being debated.
In this study, we discuss the GIA-derived gravity change and crustal deformation in the East Antarctic region using the previously published AIS deglaciation models and the GIA modeling code currently under development. GIA is highly dependent on the viscosity structure of the Earth’s mantle as well as on the changes in surface loads. Therefore, we will conduct the numerical experiments with the extensive GIA model parameters and show the effects of the GIA-induced geodetic signals on the inferences of current and past ice mass fluctuations quantitatively.

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Quantifying the contributions of erosion and tectonics towards the lowering of subglacial topography beneath the Antarctic and Greenland Ice Sheets

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The Antarctic and Greenland Ice Sheets contain a combined volume of ice equivalent to ~65 metres of global mean sea level rise. Both ice sheets are likely to diminish in volume and thus contribute to global sea level rise over the coming centuries. Many outlet glaciers in Antarctica and Greenland are underlain by deep subglacial troughs; these glacial catchments have been identified as particularly vulnerable to sustained and potentially irreversible future ice mass loss. However, the origin of these subglacial landscapes remains unclear, as do the relative contributions of tectonic processes and fluvial/glacial erosion towards trough development.

Here we combine geomorphological analysis with gravity and magnetic modelling to constrain the processes responsible for the development of subglacial trough systems in northern Greenland and East Antarctica. We find that the landscapes in northern Greenland retain a stronger fluvial signature than in East Antarctica and have been less heavily modified by glacial erosion, which may reflect differences in the duration of glaciation and/or landscape erodibility.

Moreover, the morphology of several subglacial troughs in both Antarctica and Greenland is inconsistent with the modern ice flow regime. In some cases, we propose that these features formed via fault-induced subsidence prior to glacial inception, whereas other troughs were at least partially overdeepened by glacial erosion beneath an earlier ice sheet with a more restricted configuration than the present-day. This in turn yields insights into Antarctic and Greenland ice sheet behaviour and extent during past warmer climate intervals potentially analogous to future climate scenarios.

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An ensemble of glacial isostatic adjustment models for Antarctica derived from an ensemble of ice history models

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Understanding the response of the solid earth to past ice sheet change is an ongoing challenge for the estimation of present-day mass change from satellite gravimetry. The magnitude of the correction that must be made to account for ongoing solid earth deformation is similar to the change in the mass of the ice sheet itself, making estimates of change sensitive to this correction. We use a Maxwell-rheology sea level solver in combination with an ensemble of earth and deglacial history models to generate 2000 unique glacial isostatic adjustment (GIA) models. We compare each GIA ensemble member to a new GPS-derived surface velocity field. The GIA models are scored for the number of data points which they match within the uplift error, the number of points which show the correct sign of change and the overall root-mean-square error between the modelled and observed data. We assess the performance of the models over four key Antarctic regions, with a particular focus on investigating the likelihood of a Holocene readvance within the Weddell Sea region.

1415

Heat flow in southern Australia and connections with East Antarctica

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Viscosity and melt generation at the base of ice sheets are critically dependent upon heat flow. Yet subglacial heat flow is poorly constrained due to the logistical challenges of obtaining boreholes that intersect bedrock beneath thick ice cover. Currently, continental estimates of Antarctic heat flow are derived from geophysical methods that provide ambiguous constraints of crustal heat sources, despite their demonstrated importance for accurate predictions of future ice sheet behaviour. This study pursues an alternative approach by using heat flow measurements from the Coompana Province of southern Australia, which represents the geological counterpart of Wilkes Land, East Antarctica. We present nine new surface heat flow estimates from this previously uncharacterised region, ranging from 40–70 mW/m2 with an average of 57 ± 3 mW/m2. These values compare favourably to recent geophysically-derived estimates of 50–75 mW/m2 for the Totten Glacier catchment, and to the single in situ measurement of 75 mW/m2 from Law Dome. However, they are appreciably lower than the range of 56–120 mW/m2 (83 ± 13 mW/m2 average) for the abnormally enriched Proterozoic terranes of the Central Australian Heat Flow Province. This study provides the first regional heat flow map of geological provinces formerly contiguous with East Antarctica through the application of continent-scale heat flow datasets tied to a Jurassic plate tectonic reconstruction for Gondwana. Our approach reveals several discrepancies with current heat flow models derived from geophysical methods and provides a more robust analysis of subglacial heat flow using this plate tectonic synthesis as a proxy for East Antarctica.

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Heterogeneity in the deep Earth beneath East Antarctica in the 60-160 degree E sector.

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Interactions between the solid Earth and cryosphere, in modelling glacial isostatic adjustment, for example, have previously assumed a 1D Earth structure. More recent studies, however, have shown the merit of approaches that make use of a 3D Earth structure. While West Antarctica and parts of central Antarctica have much improved constraints on the heterogeneity of the deep Earth through recent geophysical studies, the 60-160 degree E sector of East Antarctica is less-well constrained.
This contribution makes use of newly recorded seismic signals in the region between Casey and Davis stations, geophysical data compilations, and plate reconstructions to construct the likely variation of physical properties in the lithosphere and asthenosphere in this region. We make use of newly written software for data synthesis in 3D, and volumetric visualisations in our analyses.
We present the results of this survey of, observed and probable, heterogeneity in the deep Earth across this sector. An important component of the synthesis are the associated uncertainties and identification of the most poorly constrained regions. It is likely that the region is more variable than previously thought with changes in physical properties being identified around the coast, and being probable in the region between the coast and the pole. We aim to make our results available to the interdisciplinary community, including ice sheet modellers, in the near future.

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Bedrock uplift in response to recent ice-mass change on northern Marguerite Bay, Antarctic Peninsula

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Rapid regional climate warming in the Antarctic Peninsula has led to several major ice shelves retreating, and eventually collapsing, since the 1970s. In response, feeding glaciers have exhibited rapid acceleration and thinning, and this dynamic ice unloading induces a solid Earth response which can be measured by geodetic observations. We investigate ice-mass change and bedrock deformation in the northern Marguerite Bay (NMB) region of the Antarctic Peninsula from ~2002 to 2018 in order to provide new constraints on Earth rheology. The mass balance estimation over this region suggests that the ice mass loss reduced around the Rothera research station since ~2012 and the Muller Ice Shelf since ~2009 compared to 2004-2012 and 2002-2009, respectively. GPS measurements of bedrock uplift in NMB show time-varying rates of uplift varying between ~2.2 and 7.0 mm/year over 2002-2018. A comparison between GPS and modeled viscoelastic deformation up to 2015 suggests an upper mantle viscosity of ~0.1-80×10^{18} Pa s but allows a wide range of effective elastic lithosphere thickness for NMB. This viscosity estimate is consistent with a north-south gradient in viscosity suggested by previous studies focused on specific regions within the Antarctic Peninsula and adds further evidence of low viscosity upper mantle in the northern Antarctic Peninsula.

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Recent ice-mass change and its effect on viscoelastic deformation rates around the northern Antarctic Peninsula

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The rapid viscoelastic uplift measured around the northern Antarctic Peninsula due to ice mass loss since ~2002, solid Earth modeling suggesting the upper mantle viscosities of $\sim 6\times10^{17}$ - 2×10^{18} Pa s and a wide range of lithosphere thicknesses. This finding was based on only one GPS station bedrock uplift. We extend the continuous GPS time series to include 5 additional years and the additional consideration of the horizontal components of deformation. GPS observations show strong uplift from 2002 to 2011 followed by reduced uplift rates to 2018. The observed horizontal displacements are directed towards the south-west, in accord with the known and ongoing ice-mass loss in the eastern Peninsula. The modeling of the east coordinate component confirms the viscosity range suggested by the uplift rates alone and providing important, largely independent, confirmation of that result. We also expand on the limited spatial coverage of the GPS data using Sentinel-1A C-band InSAR data from 2014.9-2017.8. In the Larsen-B region, large relative line-of-sight displacements are observed at outlet glaciers of low elevation where ice unloading is high. InSAR also indicates that mass loss around the southern part of the Larsen-A region is higher relative to the northern part. Comparing these InSAR data to updated viscoelastic modeling for the Larsen-B region refines the understanding of lithospheric thickness, demonstrating a poor fit to models with a thin lithosphere. InSAR shows a good agreement for lithospheric thicknesses in the range of ~85-160 km with the upper-mantle viscosities preferred from comparison with the GPS time series.

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Consistently Re-processed Geodetic GNSS Data in Antarctica as a Basis for Geodynamic Applications: the GIANT-REGAIN Project

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In-situ GNSS measurements taken at bedrock markers provide information and constraints on a variety of phenomena. Among these, glacial-isostatic adjustment (GIA) is of utmost interest because it links ice-mass change, solid Earth response and sea-level change. However, in Antarctica ice mass balance studies based on satellite gravimetry suffer most from the large uncertainty of GIA predictions. Therefore, we aim to strive for a comprehensive analysis of all geodetic GNSS data available in Antarctica to improve GIA models.
For this purpose, the “Geodynamics in Antarctica based on Reprocessing GNSS Data Initiative” (GIANT-REGAIN) was launched under the umbrella of the Scientific Committee on Antarctic Research, Expert Group on Geodetic Infrastructure in Antarctica (EG GIANT).
We compiled a data set comprising recordings from more than 250 permanent and episodic GNSS sites. The period of observations starts with the beginning of geodetic GNSS measurements in Antarctica in the mid-1990s and is limited to the end of 2017. The process of data and metadata acquisition will be reported, which entailed major efforts. The data set is being re-processed at three analysis centres (TUD, UTAS and OSU). Thus, effects arising from the application of different processing strategies and algorithms (“software noise”) are investigated, and the reliability of inferred results will be cross-checked. As a core product we aim for one consistent set of vertical and horizontal deformation rates together with uncertainties that can be used for further analyses in Antarctic geodynamics, especially to improve our understanding of GIA.

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How to combine satellite gravimetry, satellite altimetry, and firn model products to resolve GIA over ice sheets?

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Solid-earth deformation through glacial-isostatic adjustment (GIA) is a major component in gravimetric mass balance studies in polar regions. In addition to GIA forward modeling products, the present-day GIA signal over ice sheets can be separated from ice mass changes, e.g. by combining satellite gravimetry, satellite altimetry and firn model products.

We present results of a sensitivity study where we investigated an inverse GIA estimation approach over Antarctica regarding the choice of degree-1 and C_{20} coefficients, different altimetry missions, time epochs, and the uncertainty of firn processes. The latter are characterized empirically using differences between two regional climate model products. Further, we tested a similar signal separation approach over the Greenland ice sheet. Our results demonstrate the limitations when combining observations of both geodetic sensors and firn model products, e.g. through the reconcilement of spatial resolution of data sets, uncertainties of low-degree harmonics, and firn/ice density assumptions for regional applications.

Moreover, we treat the signal separation over ice sheets as a parameter estimation problem in a global consistent framework. On the basis of these findings we will implement the estimation of the GIA signal from satellite observations in a global fingerprint inversion where it will be co-estimated with all parts of the global sea-level budget.

1508

How can geophysical imaging help constrain mantle viscosity to improve glacial isostatic adjustment models?

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Glacial Isostatic Adjustment (GIA) represents the viscous deformation associated with Earth's re-estabilishment of isostatic equilibrium after a significant ice sheet mass change. GIA occurs over thousands of years, depending on mantle viscosity, and thus Greenland and Antarctica are still responding to melting that occurred over the last 10,000 years or more. Because this GIA response overprints instantaneous uplift resulting from present-day melting, our models for GIA directly affect current estimates of ice loss and predictions of future sea level rise. Despite this, GIA analysis is beset with uncertainties regarding ice sheet history and Earth structure and many GIA models do not reproduce current observations of surface uplift.

We present an analysis for how geophysical data – specifically the combination of magnetotelluric (MT) and seismic data – can improve estimates of mantle viscosity and therefore help to constrain GIA models. We show that seismic and MT data together give the best possible constraints on upper mantle temperature, which is the primary control on viscosity, as well as providing important constraints on surface heat flow. In addition, MT data can be used to constrain the hydrogen content of mantle minerals, which is another major control on their viscosity. We show results from polar regions such as Svalbard, where the geophysical data significantly improved constraints on mantle viscosity compared to those that can be inferred from GIA data alone, and current research on the Greenland Ice Sheet, where we are collecting the first ever MT data to model lateral variations in mantle viscosity.

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A new geothermal heat flux map of Antarctica determined by seismology

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The seismic structure of the lithosphere is directly related to the thermal structure of the interior of the Earth. Thus, providing information about geothermal heat flux (GHF), which is an important boundary condition for modeling the dynamic Antarctic ice-sheet. We combine two latest Antarctic seismic models and make a comparison to the seismic structure of the continental US, whose GHF is well sampled and accurately measured. Local GHF estimates in Antarctica are then derived based on the hypothesis that similar mantle structures lead to similar GHFs. Based on this method, we show that the new GHF map has improved resolution and lower uncertainties compared to earlier seismologically derived maps, owing to the greatly improved tomographic images. Furthermore, the result is consistent with most of the independent local measurements. Overall, we find that the new map presents a West-East Antarctica dichotomy which has been shown in previous maps. One striking result is that we do not observe pervasive high GHF in the central region of West Antarctica. Instead, the new map reveals relatively low GHF in the central West Antarctic Rift system near the Siple Coast, coherent with a local measurement made at Siple Dome. Particularly, we find that high GHF estimates (> 80 mW/m2) emerge in the Thwaites Glacier region that is consistent with earlier radar-derived result and high GHF (>75 mW/m2) throughout the southern Transantarctic Mountains (sTAM) in the vicinity of the Titan Dome and Hercules Dome, co-located with the sub-ice lakes.

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Towards a reconciled heat flow map for Antarctica: Aq1

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Subglacial heat flow is used as a boundary condition for ice sheet models and in understanding the tectonic development and properties of the lithosphere. Existing Antarctic heat flow estimates at continental scale are based on univariate modelling of a geothermal gradient and do not agree. Disparities arise from assumptions regarding lithospheric properties such as crustal heat production, upper mantle composition and dynamic neotectonics.

We employ a 'similarity approach' that compares Antarctic observables with observables linked to existing high-quality heat flow measurements from global compilations. Previous studies that use similarity to interpolate heat flow values elsewhere, utilise datasets that do not extend to the Antarctic interior with sufficient reliability. Here, we optimise the similarity approach for existing Antarctic geophysical and geological datasets by applying a careful sensitivity analysis and introduce weighting of observables. Observables used include topography, distance to volcanoes, geophysical data sets, and derived products such as depth to Curie temperature isotherm, seismic wave speed and curvature of gravity field. We also include geological observations. In total, 15 observables are used.

The new heat flow map, Aq1, is presented together with uncertainty and measures of information entropy in widely used formats. We also provide the complete workflow as open source Python code relying on the agrid package. The complete computational framework allows for testing of alternative inputs and updates as new data becomes available.

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Separation of tectonic and glacial isostatic adjustment signals in East Antarctica from GPS horizontal velocities

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Observations of deformation due to glacial isostatic adjustment (GIA) provide a crucial constraint on the Earth's response to ice unloading, giving insight to the contribution of ice-covered regions to global sea level rise. However, accurate measurement of local geodetic motion presents a challenge due to tectonic plate rotation. The horizontal velocity component measured at GPS stations in East Antarctica has a plate rotation signal over an order of magnitude greater than the expected GIA motion. Incomplete separation of these components thus introduces significant bias into measured GIA velocities.

We present a study applying signal separation techniques to sets of synthetic data that replicate a combination of plate rotation and GIA-like horizontal velocities at 36 GPS stations across East Antarctica. We compare two approaches for removing the plate rotation component, where either: 1) the stations are unweighted; or 2) each station is weighted based on the spatial density of neighbouring stations. The synthetic tests show the spatial weighting of stations has a very significant effect on our ability to recover synthetic GIA signals.

We apply this second approach to observed horizontal velocities from 36 GPS stations across East Antarctica, and estimate the systematic uncertainty based on our study using synthetic data. We measure statistically significant (2σ level) GIA horizontal velocities at 25 of the 36 stations. Our techniques and open source software provide a toolbox not only to measure the GIA signal using current GPS installations but also to optimise the siting of stations in future campaigns.

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Feedback between ice dynamics and bedrock deformation for the LGM ice sheet in Antarctica

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Over glacial-interglacial cycles, the evolution of an ice sheet is influenced by Glacial isostatic adjustment (GIA) via two negative feedback loops. Firstly, vertical bedrock deformation due to a changing ice load alters ice-sheet surface elevation. Secondly, bedrock deformation will change the location of the grounding line of the ice sheet. GIA is mainly determined by the viscosity of the interior of the solid Earth which is radially and laterally varying. Underneath the Antarctic ice sheet, there are relatively low viscosities in West Antarctica and higher viscosities in East Antarctica, which affect the response time of the above mentioned feedbacks. However, most ice-dynamic models do not consider the lateral variations of the viscosity in the GIA feedback loops when simulating the evolution of the Antarctic ice sheet. We present a method to couple ANICE, a 3-D ice-sheet model, to a 3-D GIA finite element model. In this method the model computations alternate between the ice-sheet and GIA model until convergence of the ice thickness occurs at each timestep. We simulate the evolution of the Antarctic ice sheet from 120 000 years ago to the present, considering 1D and non-linear 3D rheologies. The results of the coupled simulation will be discussed and compared to results of the uncoupled ice-sheet model.

1380

Understanding the controls on Glacial Isostatic Adjustment across West Antarctica

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Solid Earth deformation across Antarctica, triggered by past ice-mass change, contaminates measurements of present-day ice-mass change and has the potential to influence future ice-sheet dynamics. In order to model this process, known as glacial isostatic adjustment (GIA), it is necessary to determine what periods of past ice-mass change dominate the contemporary GIA signal. It is often assumed that the spatial pattern of GIA reflects ice extent change since the Last Glacial Maximum (LGM), and this will hold true in regions where the mantle relaxes slowly, i.e. in high viscosity regions. However, recent observational and modelling studies suggest that upper mantle viscosities beneath parts of West Antarctica may be much lower than the global average. In such regions mantle relaxation will take place more quickly and the response to recent ice-mass change will dominate the deformation signal. Here, we use a GIA model that considers 3D variations in Earth rheology to quantify spatially variable relaxation times and identify which periods of past West Antarctic ice-mass change have the greatest influence on the current GIA signal.

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Upper mantle viscosity structure and lithospheric thickness of Antarctica estimated from recent seismic models

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Upper mantle viscosity structure and lithospheric thickness vary significantly across Antarctica, leading to strong differences in glacial isostatic adjustment (GIA). We produce new maps of these parameters using two new seismic models. Shen et al. [2018] use receiver functions and Rayleigh wave velocities to develop a higher resolution model for the upper 200 km beneath Central and West Antarctica. Lloyd et al [2019] use adjoint tomography to invert three-component earthquake waveforms for structure down to 800 km beneath Antarctica and adjacent oceanic regions. We estimate the mantle viscosity from the seismic structure assuming laboratory-derived relationships between seismic velocity, temperature, and rheology. Choice of parameters for the conversion is guided by recent estimates of mantle viscosity from geodetic measurements. We also compare several different methods of estimating lithospheric thickness. The mantle viscosity estimates indicate several orders of magnitude variation, with low viscosity (< 10^{19} Pa s) beneath the Amundsen Sea Embayment (ASE) and the Antarctic Peninsula, suggesting a characteristic GIA time scale on the order of a hundred years. Lithospheric thickness is also highly variable, ranging from around 60 km in parts of West Antarctica to greater than 200 km beneath East Antarctica. Thin lithosphere and low viscosity between ASE and the Antarctic Peninsula likely result from the thermal effects of a slab window as the Phoenix-Antarctic plate boundary migrated northward. Low viscosity regions beneath the ASE and Marie Byrd Land coast connect to an offshore anomaly at depths of ~ 250 km, suggesting the involvement of larger-scale geodynamic processes.

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Error Budgets for GNSS-derived Crustal Motion Velocities in Antarctica: Implications for Constraining GIA Models

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Crustal displacement rates and patterns derived from GNSS measurements are a dominant constraint on GIA models for Antarctica, because other types of data constraints are sparse. Measurements accurate at the 1 mm/yr level or less would be optimal to test for the 'best' GIA model parameters through comparison of model-predicted and measured crustal motions. There are several confounding issues to achieving this level. Implementing common reference frames for model-predicted and measured motions is essential. Computing and removing the component of crustal displacement due to the elastic response to contemporary ice mass change is crucial in Antarctica, but acquisition of requisite mass balance data across our network extent is challenging and the methodology to best estimate elastic response is not yet robust. Like most high-latitude GNSS networks, ANET sites have utilized chokering antennas covered with SCIGN radomes. It is well known that snow and ice on antenna and radome exteriors causes data scatter and errors in positioning. Here we investigate an environmental effect, largely unique to Antarctica, that degrades the accuracy of velocity estimates – excursions in the daily position time series arising from intrusion of spindrift snow and subsequent accumulation of ice and meltwater inside the antenna chokerings, beneath the covering radome. We characterize the position time series and velocity estimates before and after mitigation of antenna icing and from data cleaning approaches. We find regional differences in icing-related errors, pointing to a need for a weighting scheme accounting for this when GNSS-derived velocities are compared with GIA model predictions.

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Spatial Scale of Crustal Deformation Patterns across West Antarctica

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The geodetic component of the Antarctic Polar Earth Observing Network (ANET-POLENET) provides high-precision bedrock crustal velocities across most of West Antarctica. Observed vertical and horizontal crustal displacements show complex patterns and vary strongly from the Transantarctic Mountains to the West Antarctic coastal region. Crustal deformation patterns derived from 1D glacial isostatic adjustment models vary spatially between maximum uplift to subsidence on scales between 750 and 1250 km, the response from two dominant LGM ice load centers in the Weddell and Ross embayment regions. For 3D GIA models, the spatial distance between predicted uplift and subsidence maxima reduces to 500 km in sectors of West Antarctica where earth rheology is weak and ice load changes continue to the Late Holocene. Crustal displacements measured from ANET continuous GNSS time series document spatial changes from uplift to subsidence over significantly shorter distances, on the order of 300-500 km. The measured spatial patterns in crustal deformation are of similar scale to lateral variations in seismic velocities and derived earth structure as resolved by recent seismic studies, highlighting the need for 3D earth models to understand GIA in Antarctica. Improved resolution of the deformation pattern associated with an uplift center and subsiding moat around it in the Amundsen Embayment region is provided by initial velocity solutions from newly deployed GNSS sites that have densified our measurement network. Our new results have important implications for patterns and rates of ice sheet – solid earth feedbacks.

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Active subglacial volcanism in West Antarctica as assessed by airborne geophysics: Distribution and context

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A combination of aerogeophysics, seismic observations and direct observation from ice cores and subglacial sampling has revealed at least 21 sites under the West Antarctic Ice sheet consistent with active volcanism (where active is defined as volcanism that has interacted with the current manifestation of the West Antarctic Ice Sheet). Coverage of these datasets is heterogenous, potentially biasing the apparent distribution of these features. Also, the products of volcanic activity under thinner ice characterized by relatively fast flow are more prone to erosion and removal by the ice sheet, and therefore potentially underrepresented. Unsurprisingly, the sites of active subglacial volcanism we have identified often overlap with areas of relatively thick ice and slow ice surface flow, both of which are critical conditions for the preservation of volcanic records. Overall, we find the majority of active subglacial volcanic sites in West Antarctica concentrate strongly along the crustal thickness gradients bounding the central West Antarctic Rift System, complemented by intra-rift sites associated with the Amundsen Sea to Siple Coast lithospheric transition.

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SESSION 16

ANTARCTIC SUBGLACIAL SYSTEMS: OBSERVATIONS, MEASUREMENTS AND MODELLING

INTERNATIONAL SCIENCE COUNCIL
SCAR
SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

Martin Siegert
Winnie Chu, Dusty Schroeder, Christine Dow

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Subglacial precipitates record East Antarctica's response to 1-2 °C warming

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At ~400 thousand years before present, during MIS 11, Earth was 1-2°C warmer and sea level was 6-21m higher than present. Sea level estimates in excess of 10m, however, have been discounted as these require contribution from the East Antarctic Ice Sheet, which has been argued to have remained stable at MIS 11 and for millions of years prior. Here, we show how chemical precipitates that formed beneath the ice sheet record the magnitude of East Antarctic ice loss during MIS 11. Within the Wilkes Basin, precipitates record the accumulation of 234U, the product of rock-water contact within an isolated subglacial reservoir, up to 20 times higher than marine waters. The timescales of 234U enrichment place the reservoir inception to MIS 11. Informed by the observed 234U cycling in the Laurentide ice sheet, where 234U accumulated during periods of ice stability and is purged in response to deglaciation, we interpret our East Antarctic dataset to record ice loss within the Wilkes Basin at MIS 11. The 234U ingrowth within the Wilkes Basin is shared by the McMurdo Dry Valley brines, supporting brine origination from the Wilkes Basin. The requirement that Dry Valley salt and bacteria are marine derived implies that MIS 11 ice loss in the sub-sea level Wilkes Basin was coupled with marine flooding. Collectively these data indicate that the last time Earth warmed 1-2°C, the ice sheet margin at the Wilkes Basin retreated at least 700km inland from the current position, contributing >3-4m to sea level rise.

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Indications for subglacial bathymetric control on ice shelf stability in western Dronning Maud Land, East Antarctica

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The floating ice shelves of Antarctica play a major role in stabilizing the grounded continental ice sheets. Ice shelf thinning due to basal melting with subsequent loss of buttressing at pinning points are prominent contributors to increased ice sheet drainage and subsequent sea level rise. The catchment to the ice shelves of western Dronning Maud Land currently comprises an ice volume equivalent to 0.95 meters of sea level. Since basal melting predominantly depends on ice-ocean interactions, it is vital to attain consistent bathymetric models as boundary conditions for estimating water and heat exchange beneath the ice shelves. We have constructed bathymetric models beneath the Ekström, Atka, Jelbart, Fimbul and Vigrid ice shelves by inverting airborne gravity data, tied to seismically-derived depth reference points. High-resolution magnetic anomaly data across these ice shelves are used to interpret shallow subsurface geological variations whose effects on density variability are accounted for during the inversion. Our bathymetric models reveal deep glacial troughs beneath the ice shelves and sills close to the continental shelf breaks, which currently limit the entry of Warm Deep Water from the Southern Ocean. The average thermocline depth and the average depths of gateways crossing the sills into the sub-ice cavities are similar, leading us to suggest a high sensitivity for these ice shelves to future changes in thermocline depth. Once a significant amount of warm water overtops the sills, the deep troughs will allow for fast access to the grounding line leading to a surge in basal melt rates.

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Trace element dispersal by an Antarctic subglacial sediment plume

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Subglacial environments are distinct cryospheric sources of dissolved nutrients to the euphotic zone, yet their contributions to trace element biogeochemistry remain uncertain. Additionally, the speciation of key bio-limiting micronutrients, such as iron, present within sediment plumes arising from subglacial meltwater discharge is unknown. Enhanced microbial respiration, high weathering rates, and limited diffusion of oxygen, increase the solubility of redox sensitive elements, such as iron (Fe) and manganese (Mn), which enter the ocean as buoyant turbid plumes. Here we characterize the signature, dispersion and physicochemical speciation of bioactive trace metals in a glacial sediment plume and speculate on the geochemical setting beneath west Antarctic Peninsula glaciers. This work reveals sediment plumes arising from subglacial meltwater discharge are important subsurface sources of dissolved and labile particulate Fe (82-100% of total particulate Fe) to resident phytoplankton communities. Our analyses reveal strong co-variation between dissolved and labile particulate pools at plume depths (70-150m), indicating exchange over short length scales. Given that Antarctic glaciers are susceptible to rapid changes in the warming climate, the interface between glaciers and the coastal ocean is poised to be an important control on the quantity and quality of micronutrients transported to downstream nutrient-limited phytoplankton communities.

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Improved ice sheet bed topography of Antarctica from satellite images: BedImage Antarctica

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The bedrock topography of Antarctica is a critical parameter for ice sheet models and for understanding the geological history of the continent. Recent compilations using radar and gravity data have greatly improved the coverage and resolution of the sub-ice-sheet bedrock surface, but many regions remain poorly mapped. Here we use satellite-image-derived surface ice-sheet morphology and surface ice flow velocity to quantitatively improve the mapping of Antarctica's bedrock topography below the ice sheet through a newly developed technique. The analysis is based upon an inversion of the driving stress equation, with surface velocity used as a parameter to estimate internal and near-basal flow. We calibrate and convolve the approach using gridded BEDMAP2 and BedMachine data and check this against new radar profiles. The result is a detailed 1km resolution comprehensive model of the Antarctic bed. Comparison with BEDMAP2 cells in East Antarctica shows a 0.85 R2 correlation and a standard deviation of 270.6 m. This "BedImage" model provides useful detail in many inland areas that were previously poorly mapped. Additionally, we present sub-kilometre-scale maps of two areas that have ice conditions suitable for higher resolution models.

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Subglacial lake formation in response to thermal conductivity contrasts with or without subglacial topography

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Geothermal heat flux (GHF) is an essential boundary condition for producing accurate numerical models of basal melting, but the magnitude and variation of GHF is poorly characterized beneath polar ice sheets. In this study, we explore small-scale (~1 to 10 km) thermal-refractive effects on GHF at subglacial boundaries resulting from lateral thermal conductivity contrasts associated with subglacial topography and geologic contacts. Heat flux can preferentially flow into or around a subglacial valley depending upon the thermal conductivity contrast with underlying bedrock with magnitudes at the glacial-basement interface ±20 to 40% of regional geothermal heat flux and temperature anomalies on the order of ±10ºC. When bedrock is more conductive than ice, heat flows around valleys and into peaks. Even without topography, subglacial geologic contacts can produce heat flux and temperature anomalies of similar magnitude. Heat flow and temperature are locally increased on the thermally conductive side, adjacent to the geologic contact. To estimate the importance of thermal refractive effects, we analyze the characteristics of 378 subglacial lake localities in East Antarctica. We find 260 lakes occur in regions of thick ice, >2.5 km, which likely reach the melting point as a result of ordinary conduction. However, a significant fraction (~80%) of lakes lies in regions of thin ice with slow velocities. The majority of remaining lakes occur in regions with minimal subglacial topography, indicating thermal refraction due to subglacial contacts may be a significant contributor to subglacial melting. Therefore, models of subglacial geology are required to improve glacial models.

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Grounding zone subglacial properties from calibrated active source seismic methods, Whillans Ice Stream, West Antarctic

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The presence of water, sediment, or bedrock beneath glaciers and ice sheets can control ice flow by promoting sliding at the ice-bed interface and deformation of the bed. These conditions can change rapidly, and the potential for change is not captured by commonly employed inversion techniques used to infer bed friction. Aspects of subglacial conditions can be detected remotely using radar and active source seismic methods. While radar techniques provide extensive spatial coverage, seismic techniques provide direct estimates of elastic properties. Here we present novel calibrated active source seismic estimates of subglacial properties from the grounding zone of Whillans Ice Stream, revealing an abrupt transition to the ocean cavity over less than 500 m. The grounded portion of the ice stream is underlain by a substrate that is relatively stiff when compared with the deformable till found elsewhere beneath the ice stream. We also detect thin layers of subglacial water several kilometres upstream of the ocean cavity. The presence of stiff subglacial sediment and thin water layers upstream of the grounding zone support previous studies that have proposed the dewatering of sediment within the grounding zone and the pumping of ocean water into the subglacial system. We compare our findings with existing radar estimates of the transition and highlight the geophysical and direct access program current being undertaken by the New Zealand Antarctic Research Institute and the Antarctic Science Platform.

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Subglacial sedimentary basin distribution in Antarctica unveiled

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Antarctica preserves the largest ice-sheet on Earth. Understanding subglacial sedimentary basin distribution is essential for studying ice sheet behaviour, as it forms an important basal boundary condition for ice sheet dynamics. However, the subglacial sedimentary basin distribution is poorly known in Antarctica. The thick ice sheet with limited outcrop makes it difficult to directly map sedimentary basins, and until now continental-scale sedimentary basin models only have been derived from interpolation of sparse seismic data and inversion of decompensative gravity anomaly. Here we present a high-resolution subglacial sedimentary basin likelihood map using a supervised machine learning method based on continental compilations of geophysical and remote sensing datasets. Classification uncertainty is simultaneously derived from information entropy. The results confirm the existence of subglacial sedimentary basins in West Antarctica and in general define the margins and extents of sedimentary basins in detail. Specifically, in West Antarctica Rift System, model delimits the boundary between sedimentary basins and volcanic rocks. Further, our model shows more widely distributed subglacial sedimentary basins in East Antarctica than been previously recognized. Properties of geophysical and remote sensing data in Recovery Glaciers suggest a high probability of sedimentary basin preservation.

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Geostatistical Simulations of Subglacial Topography and Implications for Water Routing

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Subglacial topography is an important driver of ice sheet movement and subglacial water flow. Bed topography is primarily measured with ice-penetrating radar, but large gaps in data must be interpolated. Topographic interpolations are frequently made with kriging or mass conservation, where ice flow dynamics are used to constrain bed geometry. However, these techniques generate bed topography that is unrealistically smooth, which biases subglacial water routing models and makes it difficult to rigorously quantify uncertainty in subglacial drainage behavior. To address this challenge, we generate geostatistical simulations of bed topography so that the interpolated topography reproduces the spatial statistics of the radar data. We demonstrate a protocol for performing geostatistical simulations of bed topography that uses mass conservation topography as a soft constraint. We then apply a water routing model to these simulations and show that some flowpaths change significantly with each topographic realization. We discuss the implications of our findings for quantifying uncertainty in bed conditions, topographic controls on subglacial water routing, and making hydrological interpretations using interpolated bed topography.

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Provenance of gravel- and sand-sized sediment from both the ice shelf and shallowest seafloor at the HWD-2b site, mid Ross Ice Shelf, Antarctica

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In 2017, the Aotearoa New Zealand Ross Ice Shelf Programme drilled through the Ross Ice Shelf at site HWD-2b [Latitude -80.658, Longitude 174.463]. Presently, HWD-2b lies under the ice flow path from the Liv Glacier in the Transantarctic Mountains. Sediment was recovered from both the ice shelf and by gravity core from the seafloor. Petrographic study of this material aimed to determine whether the ice shelf and seafloor sediment had a shared source. Two size fractions were examined for both the ice shelf and seafloor samples. The pebble-sized fraction was petrographically described in hand specimen and thin section. The plutonic pebbles have a mineralogy consistent with quartz diorite and tonalite. The sandstone pebbles are quartziferous and are typically undeformed and unmetamorphosed. Limestone and volcanic lithologies are not identified. The sand-sized fraction thin sections were stained for potassium and alkali feldspar and point counted (n:310 grains) by the Gazzi-Dickinson method. The ice shelf and seafloor samples are quartz- and plagioclase feldspar-rich, with only a minor lithic/alkali feldspar component. Both samples are likely from similar source rocks, equivalent to a quartz diorite, quartz gabbro or tonalite. This suggests the source of both samples in both size fractions is rich in Ferrar Dolerite and a quartziferous sandstone source, perhaps like Byrd Group or Beacon Supergroup lithologies. These lithologies are consistent with a Central Transantarctic Mountain source, such as is seen around the Liv Glacier or Beardmore Glacier. A shared provenance has implications for ice sheet retreat models since the last glacial maximum.

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Bed diagnosis in the Dome Fuji region, East Antarctica, using airborne radar data and englacial attenuation estimates

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Radar reflectivity of the ice-sheet bed has been used as a diagnostic measure of the basal conditions. Such bed diagnosis could lead to constrain magnitude and spatial pattern of geothermal flux which remains poorly known under the Antarctic Ice Sheet. Radar reflectivity can be estimated from the radar-observed bed returned power by extracting englacial attenuation. Attenuation exponentially depends on ice temperature, and can vary larger than the difference in the bed reflectivity for thawed and dry beds. In the 2016-17 austral summer, Alfred Wegener Institute carried out 150-MHz airborne radar survey for ~19,000 line kilometers in a 400-km by 400-km area including Dome Fuji, East Antarctica, where the Oldest Ice is predicted to present. Bed topography, roughness, and subglacial hydraulic potential were analyzed and subglacial lakes were preliminary mapped already. We extend that study by rigorous analysis of bed returned power. We hypothesize that model-predicted thawed area is consistent with high bed reflectivity area derived from the radar data, when englacial attenuation/temperature is derived for the correct geothermal flux. We carried out attenuation and radar reflectivity estimates for a range of geothermal flux and mapped spatial variations in the attenuation and bed reflectivity.

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Subglacial fluid compositions linked to East Antarctic ice sheet's response to Pleistocene climate cycles

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Remote sensing of the East Antarctic ice sheet (EAIS) has revealed a dynamic hydrologic system at its base that plays a major role in regulating ice sheet flow, provides a vast habitat for microbial life, facilitates chemical weathering that fuels oceanic ecosystems, and can lead to basal freezing and growth from the ice sheet base. Despite progress in detecting active subglacial hydrologic systems today, they remain virtually unconstrained over long time scales, such as the response to Pleistocene glacial-interglacial cycles. Here we explore a new record of EAIS basal fluid history in subglacial chemical precipitates from the Wilkes basin using U-series geochronology and geochemical proxies for fluid conditions and source. These samples exhibit mineralogic transitions between opal and calcite, requiring cyclic variation in basal fluid composition. We constrain the timing of these transition using 234U-230Th ages and establish a depositional timeline, which indicates rapid carbonate deposition during interglacials and slow opal growth during glacial periods. We compare mineralogic cyclicity to climate records and find statistically significant correlation between opal-calcite transitions and the benthic δ18O record on both 100kyr and shorter cycles. Collectively, these data provide direct evidence for cyclic variations in EAIS basal water that correspond with glacial-interglacial climatic cycles during MIS 8a-6d and allow us to further explore the interplay between the overlying ice sheet and subglacial aqueous systems.

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3D GPR imaging of subglacial lineations under the Rutford Ice Stream, West Antarctica

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Understanding of present-day glacier dynamics of the West Antarctic Ice Sheet is essential for the reconstruction of its past dynamics. Subglacial lineations, such as mega-scale glacial lineations and drumlins, are known to be indicative of fast ice flow. Numerous theoretical concepts based e.g. on water availability, subglacial geology and flow dynamics, attempt to explain their formation. Nevertheless, a uniform formation theory consistent with observations is still missing.
The Rutford Ice Stream (more than 2km thick, of which 1.4km is below sea level) is one such fast-flowing glacier in West Antarctica: the ice surface speed at the grounding line is >1m/day, stable over the past 30 years. The ice-bed interface is assumed to be at the pressure-melting point. Excising ground-penetrating radar (GPR) and seismic 2D profiles revealed highly elongated lineations, up to ~14 km long, up to 150 m high, and 50-500 m wide, aligned in the ice-flow direction. In one location, the deposition of sediment, arranged as a drumlin, was observed over a period of <10 years.
To study the detailed architecture of three different areas of the lineations 3D grids of GPR data with dimension 3x3km, with cross-line spacing of 20m and an inline spacing ~1.5m, were acquired in 2017/18, enabling 3D-processing and imaging of lineations. Using this unique dataset, to supplement previous findings and with data from the paleo record, we hope to better constrain the formation mechanisms for subglacial lineations and the subglacial physical conditions at the Rutford Ice Stream.

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A bed elevation model for Princess Elizabeth Land in East Antarctica

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We present a new topographic digital elevation model (DEM) for Princess Elizabeth Land (PEL) – the last remaining region in Antarctica to be surveyed. The DEM covers an area of ~900,000 km2 and was established from new airborne radio-echo sounding (RES) data collected by the ICECAP-2 consortium, led by the Polar Research Institute of China, from four different surveys since 2015. Previously, the region was characterised by an inversion using low resolution satellite gravity data across a large (>200 km wide) data-free zone to generate the Bedmap2 topographic product. We use the mass conservation (MC) method to infer bed topography across faster-flowing (>30 m yr-1) regions of the ice sheet and streamline diffusion at slower-flowing areas. Two datasets are available resolution of 1 km (to compare directly with Bedmap2) and 500 m. From the revised bed surface, we are able to better model the flow of subglacial water and assess where the hydraulic pressure is most sensitive to small ice surface gradient changes. Together with BedMachine Antarctica, and Bedmap2, this new PEL bed DEM completes the first order measurement of subglacial Antarctica – an international mission that began 70 years ago.

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The life cycle of an Antarctic active subglacial lake: A process to paleo perspective

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Research over the past decade transformed our view of the dynamic hydrological environment beneath the Antarctic ice sheet, with the ability to influence regional ice velocity, grounding-line stability, and the role of subglacial biogeochemical cycling on coastal ecosystems. Hidden beneath 10s to 1000s of meters of ice, these enigmatic hydrological systems of interconnected lakes and streams are poorly understood, largely due to the short temporal window of the ice-surface observational record from which we infer hydrological dynamics and the lack of in situ instrumentation to directly sample lake properties. We present new airborne and satellite observations that extend the current temporal record of active subglacial hydrology and explore the variability of Antarctic subglacial hydrological systems driven by the filling and draining of subglacial lakes. We then focus on Mercer Subglacial Lake beneath Mercer Ice Stream, West Antarctica, a 15 m deep lake directly accessed while in a draining phase by the Subglacial Antarctic Lakes Scientific Access (SALSA) Project in January 2019. By leveraging in situ observations of the physical and sedimentary setting of a modern active lake system, we can connect the modern observational record to the geologic past and build a conceptual understanding of how subglacial hydrological systems beneath Antarctic ice streams evolve over timescales of days to centuries while interacting with the overlying ice.

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Subglacial lake exploration: Joint UK-Chile preparations for accessing Subglacial Lake CECs, Antarctica

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The subglacial environment remains one of the least-explored places on Earth. Over recent decades more than 400 subglacial lakes have been discovered beneath the Antarctic Ice Sheet, many hidden under kilometres of ice and possibly isolated for up to millions of years. They represent one of the most inaccessible and intriguing environments on the planet and potentially hold unique records of life and of changes in the Earth system.

Subglacial Lake CECs (SLCECs) lies on the ice divide between Institute Ice Stream and Rutford Ice Stream, to the West of the Ellsworth Mountains. It was discovered in 2014 and since then, ground radar and seismic surveys have mapped its surface, bed and subglacial surroundings. The overlying ice is ~2,700 m thick, the lake surface area is ~21 km² and the maximum water depth is at least 310 m.

A joint UK-Chile collaboration is preparing to drill cleanly into SLCECs in the 2021-22 Antarctic summer, to recover water samples from the lake and sediment samples from the bed. Engineers at the British Antarctic Survey (Cambridge, UK) and Centro de Estudios Científicos (Valdivia, Chile) are in the process of upgrading the deep hot-water drill used successfully on the recent BEAMISH Project. This work involves increasing its depth capability and upgrading the cleanliness and sterility of both the drilling and the subsequent sampling. We will present the design of the drill, the proposed sampling activities and a summary of the overall lake exploration programme.

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RECAS autonomous thermal sonde for subglacial lakes exploration: current status and future development

Recas Autonomous Thermal Sonde For Subglacial Lakes Exploration: Current Status And Future Development
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To date, more than 400 relatively small subglacial reservoirs and several large lakes were discovered in Antarctica. Certainly subglacial lakes exist in Greenland. In recent years, different approaches were taken to access and directly sample subglacial water environments. RECoverable Autonomous Sonde (RECAS) allows to access subglacial lake when water remains isolated from the modern ice sheet surface during sampling. The thermal drill can melt a hole to ice sheet bottom and is able to move upwards. It includes two electrically powered thermal drill bits located at both ends of the sonde, heated body, control system, sampling chamber and coiling system. All downhole RECAS components will be sterilized prior to deployment. The melted water is not recovered from the hole and refreezes behind the sonde. The power and signal line is released from the coil inside the sonde. When sampling and monitoring are complete, the coil motor is activated and the top drill bit is powered. It is proposed that the research personnel leave the site after RECAS deployment and the sonde operates as a fully autonomous system. The power is provided by no-live-operator diesel engine generators. The first laboratory tests of the sonde subsystems were carried out during 2018-2019. The test results for the RECAS thermal heads show that the rate of penetration can be as high as 1.80–1.95 m/h. Prototype tests of the whole sonde are scheduled on the spring-summer of 2020. Field tests are planned in season 2020-2021, in the vicinity of the Chinese Antarctic research Zhongshan Station.

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Observations of a deep, narrow channel incised by subglacial water at the grounding line of Kamb Ice Stream

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Large changes in Antarctica's ice flow and discharge can be attributed to dynamics in subglacial water systems. Kamb Ice Stream is a notable example, having slowed from 500m/a to less than 10 m/a due to changes in basal water. The thickening of this ice stream now contributes significantly to the mass balance of West Antarctica. While subglacial water and basal friction are important boundary conditions for ice flow modelling, models describing the Kamb Ice stream rely on poorly constrained estimates of subglacial water. To better estimate subglacial water flux at the foot of the Kamb Ice Stream, in December 2019, we used ground based low frequency radar, phase sensitive radar (ApRES) and satelite positioning to survey a subglacial channel. The channel is likely carved by a buoyant plume of fresh water, which melts into the base of the Ross ice shelf. The narrow channel starts abruptly at the grounding zone where it incises as deep as one third of ice thickness. Results from the survey will be used to model a meltwater channel to better estimate subglacial water flux. This location is scheduled for direct access: in the 2020/21 season a borehole drilled through the ice shelf will allow a suite of observations and the installation of a permanent mooring.

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SESSION 17

GEOPHYSICAL TECHNIQUES AND ANALYSIS IN ANTARCTIC SCIENCE

Dustin Schroeder, and Kirsty Tinto
Matt Siegfried, and Rebecca Schlegel

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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A magnetic data correction workflow for sparse, four dimensional data (MDCWS-4D)

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High-quality magnetic data are important in guiding new knowledge of the solid earth in frontier regions, such as Antarctica, where these data are often among the first data collected. The difficulties of data collection in remote regions often lead to less than ideal data collection, leading to data that are sparse and four-dimensional in nature. Standard aeromagnetic data collection procedures are optimised for the (nearly) 2D data that are collected in industry-standard surveys. In this work we define and apply a robust magnetic data correction approach that is optimised to these four dimensional data. Data are corrected in three phases, first with operations operating on point data, correcting for spatio-temporal geomagnetic conditions, then operations operating on line data, adjusting for elevation differences along and between lines and finally a line-based levelling approach to bring lines into agreement while preserving data integrity. Comparison with more traditional processing approaches demonstrates superiority, however gains are variable, being relatively marginal for phase 1 (3-5%) and more substantial for phase 2 (10-35%). For the full implementation median cross-tie error reduction is 89%, reaching a final error of 8-9 nT. Residual errors are attributed to limitations in the models used for in predicting the 4D geomagnetic conditions and also some limitations of the inversion process used in phase 2. Nevertheless, data have improved utility for tectonic and glacio-tectonic interpretation and modelling, in particular quantitative approaches, which are enabled with less bias and more confidence compared to conventional processing.

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Working towards an improved bathymetry model for the Ross Ice Shelf, Antarctica

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The bathymetry beneath the Ross Ice Shelf is insufficiently known to provide useful input into ocean circulation models; yet it is the key parameter controlling the ice shelf's evolution in a warming world.

Our long-term objective is to derive an accurate and high-resolution model of the seafloor under the entire Ross Ice Shelf that blends seamlessly with regional models. To this aim we are developing a 3-D inversion algorithm capable of combining data from multiple sources. As inputs to our inversion, we currently combine ROSETTA airborne gravity data and ice surface elevation, guided by known depth points. This gives us our first generation of bathymetry models. Over time the inversion process will be further constrained by developing a shelf-wide geological model derived from improved digital processing and quantitative modelling of existing seismic and magnetic data and new aerogeophysical data (gravity, magnetic, radar).

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UAV tecnological tools for the assessment of the glacier volume retreat in Antarctic

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The use of UAV technology coupled with the zenithal photogrammetric flight methodology with geodetic adjustment, processed and analyzed in the Geographic Information System environment, allowed the quantification of the Znosko glacier tongue volume loss, relying on the geospatial products (orthophotos and digital terrain models) obtained during the austral summers of 2018, 2019 and 2020. This methodology provided high-resolution geospatial information, facilitating systemic and remote monitoring, in order to replicate the same parameters annually. Based on the quantified glacier tongue volume achieved during the study period, we propose the use of geotechnologies for glacier research.

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Using GPR to estimate the SMB at the scale of a few kilometers over Princess Ragnhild Coast, East Antarctica, and determine the representativeness of ice core data

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Simulated and measured SMB over the last centuries generally do not match well when comparing ice core and regional model data (Agosta et al. 2019). This could arise from misrepresentation of physical processes in models that affect simulated SMB (blowing snow processes are particularly difficult). Ice cores provide a detailed annual record of SMB but the signal is often reworked by post-depositional processes (Casado et al., 2019) and may be strongly influenced by local processes. The discrepancy in modeled and ice core SMB rates over the past centuries is most likely a combination of these two uncertainties. We use ground-penetrating radar (GPR) data, collected over the high accumulation Princess Ragnhild Coast (East Antarctica), to obtain an annual resolution record over several ice rises, representing conditions at a scale of a few km2. An ice core was collected on each surveyed ice rise, which allows us to place age constraints on the radar stratigraphy. By comparing this GPR-based SMB estimate with the ice core data, we calculate an error of representativity for each ice core's SMB record, estimated as the difference between the average GPR SMB over a few km2 and the ice core SMB. We then compare our corrected ice core SMB records to regional climate model SMB simulations to quantify the impact of ice core uncertainties on the modeled-observed SMB discrepancy.

The GPR system uses a 400 MHz center frequency with a maximum depth of ~60m, a vertical resolution ~30 cm in snow and a horizontal spacing ~20 cm.

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Ocean tide induced icequake swarms at the grounded margin of the Ross Ice Shelf, Antarctica

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Persistent swarms of icequakes were recorded by a broadband seismic array deployed on the Ross Ice Shelf (RIS), Antarctica from late 2014 to early 2017. These occur diurnally and appear to be driven by flexure of the shelf in response to coupling with ocean tides. The phenomenon is recorded only at stations near the grounded margin indicating that sources are local and low-magnitude. Two populations of swarms exist and are differentiated by their timing in the tidal cycle. The primary population is in phase with falling tides and the smaller secondary population appears at high tide only during spring tides. A single swarm typically consists of several 1000's of individual events occurring over several hours and usually follows a pattern of steadily increasing activity before stopping abruptly. Swarms are recorded at all times of year with varying character that can be explained by changes in tidal and environmental factors that affect the true intensity of the seismicity and our ability to accurately observe it. Event signals are dominated by Rayleigh wave energy in ~4-10 Hz band but weaker body wave arrivals in the ~20-30 Hz band are also present. A catalog of events and their locations is created using STA/LTA triggers, polarization analysis, and assumptions of RIS near-surface seismic velocities. The catalog provides information on how these swarms evolve over time and respond to environmental conditions. We anticipate these results should contribute to our understanding of dynamic processes and brittle properties of the RIS at it grounded margins.

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Seafloor depth of George VI Sound, Antarctic Peninsula, from inversion of Operation IceBridge aerogravity

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The George VI Sound (GVIS) is a long curvilinear channel on the west coast of the southern Antarctic Peninsula and separates Alexander Island from Palmer Land. The sound is a geologically complex region, presently covered by an ice shelf. One of the requirements for to understanding the ocean-ice interactions and to predict ice changes on the Antarctic Peninsula is the knowledge of the seabed beneath George VI Ice shelf (GVIIS). Here we model the bathymetry using gravity and ice thickness data from Operation IceBridge (OIB) and the International Thwaites Glacier Collaboration (ITGC) along 29 profiles over the sound. Our model is constrained with all available bathymetric information from seismic measurements and depths from CTD stations are used for comparison. Our results show that GVIIS presents depths up to 1425 m, with two deep basins (~1100 m) in the southern section separated by a 500 m high ridge. Localized areas of deeper bathymetry (450 m to 550 m) occur where there is high ice flow from glaciers grounded more than 300 m below sea level. This geometry can influence the pathways for Circumpolar Deep Water and the ice at those points might be exposed to higher oceanic heat. The water column thins significantly between the two deep basins, which could be crucial for ocean circulation models. We present a crustal density model for GVIIS and define the extent of a dense body of 2.95 gm/cm3 on the Palmer Land side.

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Filling the voids: Airborne gravity, radar and lidar surveys in Antarctica

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The gravity coverage of Antarctica has improved significantly in recent years, with airborne and satellite measurements now giving a reliable representation of the gravity field, useful for both geophysical studies and the geodetic infrastructure (improved geoid). Recent DTU Space-initiated survey activities 2013-18, in cooperation with BAS and NPI, has mapped major data voids in East Antarctica and the South Pole region, and has together with radar and magnetic data highlighted hitherto unknown structures under the ice sheet. The talk summarizes the results of the various campaigns, including a recent ESA satellite validation campaign, and also illustrates by cross-over results how older campaigns can have large gravity errors. Ongoing developments in light-weight gravity sensors allow for easier integration in small aircraft and drones. An ultimate near term goal for “piggy back” gravity applications in Antarctica could be an internationally coordinated flight campaign, filling the gaps around the perimeter of Antarctica, to allow -together with radar and lidar –the mapping of outlet glacier sub-ice topography, and thus improve overall accuracy of fluxgate “input-output” measurements of icesheet mass loss (“the Antarctic Rings”, an initiative being discussed informally with LDEO, BAS, NPI and other partners).

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Geophysical Evidences for Crustal Structures and Dynamic Settings of the Ross Sea Continental Shelf

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Because tectonic divisions and geodynamic settings of the Ross Sea are still unclear, we systematically analyzed geopotential data of RS to answer some questions.
Reduction to the pole (RTP) magnetic anomalies and pseudo-gravity anomalies clearly reflect the fluctuation trends of the Curie point. Our model of depths to the Curie point shows an uplifting zone between the Transantarctic Mountains and the Terra Rift in the Victoria Land Basin. The belt of high heat-flow anomalies given by the Curie point corresponds to the Cenozoic volcano zone, which is consistent with the surface wave low-velocity zone and its derived high heat-flow zone. It may indicate the residual weakened branch of the triple junction, which would play an important role in the Ross Sea Rift System.
After gravity effects of bedrock topography, ice cover and water body are removed from free-air gravity anomalies, complete Bouguer anomalies are corrected for variable density sedimentary strata and heat-flow given geothermal field, and then 3-D density structure with depths to the Moho are inverted. The stretching factors (β) of the whole, upper and lower crust are calculated to show that crustal thinning increases with depth. Based on Bouguer anomalies and topographical loads, the effective elastic thickness of lithosphere (Te) is also calculated, and Te varies oppositely corresponding to heat-flow anomalies. β and Te N-S zonal distribution of high and low alternating in the E-W direction may reflect that the residual branch of the triple junction controls the development pattern of the Ross Sea Rift System.

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Using an Antarctic Dataset to Expand Ultra-low Velocity Zone Investigations in the Southern Hemisphere

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Less than one-fifth of the core-mantle boundary (CMB) has been surveyed for the presence of ultra-low velocity zones (ULVZs); therefore, investigations that sample the CMB with new geometries are important to further our understanding of ULVZ origins. Using ScP waves recorded by the Transantarctic Mountains Northern Network in Antarctica, our study expands ULVZ investigations in the southern hemisphere. Our dataset samples the CMB in the vicinity of New Zealand, providing coverage between an area where ULVZ structure has been previously identified and another where prior ULVZ evidence was inconclusive. This area is of particular interest because the data sample across the boundary of the Pacific Large Low Shear Velocity Province (LLSVP). The Weddell Sea region is also well sampled, providing new information on a region that has not been previously studied. A correlative scheme between 1-D synthetic seismograms and the observed ScP data demonstrates that ULVZs are required in both regions. Modeling uncertainties limit our ability to definitively define ULVZ characteristics but also likely indicate more complex 3-D structure. Given that ULVZs are detected within, along the edge of, and far from the LLSVP, our results support the hypothesis that ULVZs are compositionally distinct from the surrounding mantle and are not solely related to partial melt. ULVZs may be ubiquitous along the CMB; however, they may be thinner in many regions than can be resolved by current methods. Mantle convection currents may sweep the ULVZs into thicker piles in some areas, pushing these anomalies toward LLSVP boundaries.

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A parametric method for snow density estimation based on ultrasonic waves

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In this paper a method for snow density estimation based on non contact ultrasound examination is described. This ground based method involves a constant frequency, air coupled ultrasound waves and incorporates a parametric method for reflected energy estimation. The paper issues theoretical considerations as well as the technological details of the addressed problem. Due to the fact that the amount of the reflected sound energy is related to the snow density the acoustic data processing scheme is presented. The theoretical model was applied to the data collected during field experiments in the vicinity of the Polish Antarctic Station Arctowski, South Shetlands, Antarctic. The results obtained permit to develop a new autonomous sensor for measurements of the snow ablation and density.

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The use of magnetotellurics in the Antarctic Interior: Examples from the Central Transantarctic Mountains and Mount Erebus – Ross Island

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Thick snow and ice cover present over the majority of the Antarctic continent necessitates geophysics to investigate both processes within the ice sheets as well as the underlying solid earth. The wide bandwidth, minimal ground disturbance coupled with the manageable logistical support associated with magnetotelluric studies, makes them attractive for Antarctic studies. The unique geography and climatic conditions of the Antarctic combined with collecting magnetotelluric data at high latitudes presents challenges not typically encountered. (1) The very-high contact resistance between electrodes and the surficial snow and ice cover can interfere with the electric field measurement. (2) Proximity to the geomagnetic poles requires verification that the magnetic source field is a vertically-propagating, horizontally polarised plane-wave. (3) The generation of 'blizstatic', localised random electric fields caused by the spin drift of moving charged snow and ice particles, produces significant noise in the electric fields during periods of strong winds. At wind speeds above ~10m/s the effect of the distortion is broad-band. Early application of magnetotellurics in the Antarctic interior was on a reduced scale to similar investigations in low latitude settings. However, our recent studies of the Central Transantarctic Mountains, and Mount Erebus – Ross Island to investigate large scale tectonic and volcanic processes are of the same scale. A ~550 km transect across the Central Transantarctic Mountains revealed that the high topography is the result of non-thermal flexural uplift. At Mount Erebus the first true 3D survey of the Antarctic Interior identifies a 'fault-valve' structural control on the magmatic system.

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Physical properties of the firn layer without coring: the possibilities and limitations of seismic refraction

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Most of the Antarctic continent is covered by a firn layer. An accurate understanding of the firn evolution is of growing importance for ice sheet modelling and remote sensing techniques. Direct measurements of the key firn properties originate from firn cores, which are sparse and labour intensive to collect. An alternate and more feasible approach is to infer firn properties from diving waves via seismic refraction. This is commonly done in a two-step process: (i) determine seismic velocity and thickness using the 1D velocity-depth inversion proposed by Wiechert-Herglotz (WH), and subsequently (ii) determine firn density using an empirical relationship proposed by Kohnen. Its application is today restricted by a limited understanding of the method's accuracy and its performance under varying climatological conditions. Here, we investigate the performance of this approach by analysing 15 sites around Antarctica that provide both direct firn density measurements and seismic surveys in close proximity. The analysis is complemented by a P-wave model which is used to systematically analyse the performance of WH for varying firn thicknesses and survey arrangements. We find that the WH method holds true for favourable measurement conditions which depend mainly on offset length, receiver spacing and the presence of summer melt. Density estimates are reasonable if WH produces good results. Our results highlight the potential of seismic refraction to retrieve information of the firn layer for carefully arranged instrumentation. We provide recommendations such that future seismic surveys can optimise field data collection for the subsequent analysis of the firn layer.

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Seismic harmonic tremors determined by local arrays and their relation to cryosphere dynamics in Lützow-Holm Bay, Antarctica

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Characteristics of seismic tremors occurring during April 2015 were investigated by seismographs at Syowa Station, in the Lutzow-Holm Bay (LHB), East Antarctica. To examine a relationship between surface environment in cryosphere variation, MODIS satellite images were utilized for comparison with detected tremor events. Since a large volume of sea-ice was discharged during April 2015, along with a few numbers of large icebergs passed through the northern edge of the fast sea-ice of LHB, it was supposed to detect characteristic seismic tremors involving cryospehre dynamics at local region. During the month, a total number of 49 tremor events including short duration ice shocks were identified. Majority of the events had their duration times more than 15 minutes, which were divided into both tremors and ice shocks. Cryospheric sources recorded by seismic tremors were classified by their origins; "crevassing events" along the large cracks inside the fast sea-ice, "discharge events" of fast sea-ice from the bay, "collision events" between iceberg and the edge of fast sea-ice, "crashing movement" between fragmentation of fast sea-ice and packed sea-ice. Particularly, strong amplitude tremors with harmonic overtones were assumed to be occurred independently from meteorological condition, along with episodic events in the cryosphere. The most plausible candidate of the source origins are collision events between bottom of drifting icebergs with the top of sea-bedding sediments/crystalline rocks at the places where the northern edges of continental shelf of LHB in which the depths of the ocean-floor could be less than 300 m from mean sea level.

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The structural and stratigraphic evolution of the Central Basin, northwestern Ross Sea (Antarctica): preliminary results

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The Central Basin is located in the northwestern Ross Sea outer continental margin and is presumably formed during the early Cenozoic (ca. 61–53 Ma) in the development of the West Antarctic Rift System. The structural and stratigraphic evolution of the Central Basin is lesser known than other marginal basins in the Ross Sea due to lack of extensive geophysical data. Here we present the newly acquired multichannel seismic profile, which crosses the middle of Central Basin, to describe the general sedimentary and basement structures. The east-west basin cross section shows up to 3 km deep (> 3 sec in TWT) basement in the middle of the basin and normal faults with tilted fault blocks or half grabens in both sides of the basin. These basement features could indicate that the Central Basin was formed by extensional tectonic events, and it is consistent with previous gravity modeling results. The sedimentary successions above the middle Miocene unit boundary show that the thickest parts of lens-shaped sediment bodies, which have discontinuos internal reflections, shifted from the middle to eastern side of the basin during the middle to late Miocene. Since the early-mid Pliocene, sheeted or mounded sediment drifts with subcontinuous internal reflections developed on the slopes and crests of bounding bathymetric highs and a lens-shaped sediment body deposited close to the Hallett Ridge. These seismic stratigraphic characteristics possibly reflect the variation of sediment supply and sedimentary processes controlled by the ice sheet dynamics and bottom current activity in the northwestern Ross Sea.

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Can integrated magnetotelluric and seismic geophysical measurements reveal subglacial groundwater and geothermal heat exchanges with the Institute Ice Stream, West Antarctica?

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The Institute Ice Stream (IIS) in the central Weddell Sea sector of the West Antarctic Ice Sheet (WAIS) is vulnerable to dynamic change and one of the largest sources of uncertainty in predictions of sea-level change from Antarctica. Fast streaming of the IIS, like that of all WAIS ice streams, relies on the presence of a substrate of basal till that dilates because it is lubricated well by water. Such till is commonly supplied by erodible sedimentary rocks emplaced in underlying crustal basins. The water is usually assumed to originate from, and flow within, a hydrological system at the ice-till interface. The underlying sedimentary rocks are therefore, in effect, assumed to be impermeable. Evidence is now growing that this assumption is wrong. Such rocks may host reservoirs of mobile groundwater that interacts hydrologically with the interfacial water system. Indeed, according to recent numerical modelling, up to half of all water available for basal lubrication may have been overlooked in models of ice flow. This situation may be typified by the IIS and its vulnerability to change therefore be controlled by a subglacial groundwater – heat flux - till system that is poorly understood. Other ice streams may experience similar hydrological controls. Here, we discuss a large forthcoming geophysical field project on the IIS that aims to understand this system by acquiring extensive magnetotelluric (MT) and seismic geophysical measurements and integrating them to constrain a next-generation numerical ice sheet model.

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Shear-wave Velocity Structure of the Crust and Upper Mantle beneath East Antarctica from Full-Waveform Ambient Noise Tomography

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The origin and tectonic evolution of various features in East Antarctica, such as the Wilkes Subglacial Basin (WSB), Aurora Subglacial Basin (ASB), Transantarctic Mountains (TAMs), and Gamburtsev Subglacial Mountains (GSM), are unconstrained due to thick ice coverage and a lack of direct geologic samples. We are modeling the crustal and upper mantle structure beneath these areas using a full-waveform tomography method to further our understanding the tectonic evolution of the continent as well as the behavior of the overlying ice sheet. A frequency-time normalization approach is employed to extract empirical Green's functions (EGFs) from ambient seismic noise, between periods of 15-340 seconds. EGF ray path coverage is dense throughout East Antarctica, indicating that our study will provide new, high resolution imaging of this area. Synthetic waveforms are simulated through a three-dimensional heterogeneous Earth model using a finite-difference wave propagation method with a grid spacing of 0.025º, which accurately reproduces Rayleigh waves at 15+ seconds. Following this, phase delays are measured between the synthetics and the data, sensitivity kernels are constructed using the scattering integral approach, and we invert using a sparse, least-squares method. Preliminary results show that slow velocities are present beneath both the WSB and ASB, possibly indicating old rift systems or other inherited tectonic structures. The transition from slow to fast velocities beneath the Northern Victoria Land section of the TAMs is consistent with thermal loading beneath the mountain range. The presence of slow velocities near the GSM may be associated with rifting along the Lambert Rift System.

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Active Glacier Processes From Machine Learning Applied to Seismic Records

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The large outlet glaciers of Antarctica, which buttress the great ice sheets from the influence of the warming ocean, evolve through a diverse set of active processes. Many of these deformation, or hydrological, processes are hidden from the view of satellite observations but give rise to seismic signals. Seismology therefore provides a viable means of further understanding and/or monitoring remote outlet glaciers if the challenge of working with the diverse range of signals can be addressed. Machine learning provides an innovative approach which complements conventional seismology techniques.
We compare unsupervised learning methods for identifying and characterizing deformation events in glacier seismic data. We use continuous data from seismic networks deployed on the Whillans Ice Stream, West Antarctica from the austral summers of 2010 and 2011. We first apply a tailored algorithm for STA/LTA event detection to build a database of glacier seismic events of various time scales and magnitudes. Then, we cluster the diverse range of signals by waveform, spectral, and polarity attributes using the k-means and self-organizing maps algorithms. Working in a high-dimensional feature space, we explore the feature groups which emerge from pattern detection. The various groups can be related to glacial seismic event types like stick-slip events, long period tremors, and crevassing. Further, data like ITS LIVE and Sentinel-I can be used to inform the other physical mechanisms that may be at play, like draining lakes or surges. Our techniques form the basis for future seismic monitoring of remote glaciers and the early identification of major change.

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Mapping subglacial sedimentary basin distribution in Antarctica using Random Forest

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The subglacial sedimentary basin distribution is key for understanding ice sheet dynamics and tectonic evolution, yet it is poorly known in Antarctica. Continental scale geophysical and remote-sensing data have the ability to reveal subglacial geology. However, cautions should be made by directly using these datasets due to the irregular data distributions and their respective ambiguities. Here, based on these continental scale datasets, we use supervised random forest method to classify the bedrock type (sedimentary rock or crystalline basement rock) in the interior of Antarctica continental shelf break. In this study, we generate training points in a regular grid to deal with heterogeneous data distribution. We present a series of studies to understand the effect to the classification result of the training point generation and distribution. We find that using only outcrop data produces a result that is likely to underestimate sedimentary basin distribution. By adding inferred result from regional geophysical studies, we improve the classification result. The uncertainty of classification and bedrock type complexity are evaluated by the information entropy. Additionally, we demonstrate the robustness of workflow by shifting the training point in 4 different directions. We conclude this method can be an effective tool to deal with heterogeneous data with limited ground truth information. In addition, this model can be easily updated with future Antarctic geophysical data compilations.

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Active source borehole seismology in the Ross Ice Shelf: applications of vertical seismic profile and cross-hole shooting techniques to study ice shelf anisotropy and temperature

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The Aotearoa Ross Ice Shelf Drilling Program visited the central Ross Ice Shelf in late 2017, drilling two hot water drill boreholes through ~370 m of ice. This rare opportunity to control the depth of both seismic receivers and sources was used to design a seismic survey targeted at the vertical distribution of anisotropic ice fabrics and temperature inside an ice shelf.

In the first borehole eight 3-component, 15 Hz seismometers were frozen into the ice at 35 m spacing between depths of 80 m and 325 m. Surface shots from a shear wave seismic source recorded on the borehole sensors show observations of shear wave splitting from multiple azimuths and offsets. A potential explanation of the observed seismic anisotropy from a synthetic crystallographic preferred orientation forward model in the ice with its implications for ice shelf deformation history is discussed.

The second borehole, located at a distance of ~560 m along the ice flow direction was used to operate a sparker borehole seismic source that was fired in 10 m spacing between depths of 70 m and 270 m. Recording of these seismic signals on the borehole seismometers allows to study the vertical variation of seismic velocities and attenuation in the ice shelf and how these are affected by ice temperature. Finite-element modelling of the effects of different anisotropic ice fabrics on synthetic traveltimes provides another constraint on character of ice anisotropy at the study site.

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First observation of an optical anisotropy in the deep glacial ice at the geographic South Pole using a laser dust logger

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We report on the observation of a directional anisotropy in the recorded intensity of back-scattered light as measured using an oriented laser dust logger. The measurement has been performed in a drill hole at the geographic South Pole, about a kilometer away from the IceCube Neutrino Observatory. The drill hole was preserved for logging access, after the SPICEcore collaboration had retrieved a 1751 meter ice core. We find the measured, optical anisotropy axis of 126° to be compatible with the local flow direction. The observation is discussed in comparison to a similar anisotropy observed by the nearby IceCube Neutrino Observatory. The measurement principle, when combined with a full-chain simulation, may in the future be used to provide a continuous record of fabric properties along the entire depth of a drill hole.

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Well-posed Use of Colour in Visualisations for Data Inference in Antarctic Sciences

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Session 17: Geophysical Techniques and Analysis In Antarctic Science

Antarctic sciences are progressing through the increasing use of remote sensing data, data compilations, and geophysical models that rely on visualisations, for example coloured contour maps, as the key medium of knowledge discovery. Such data-driven approaches benefit from careful attention to 'visual literacy' in parallel with good written or spoken communication. Antarctic research has a more frequent need for good management of resolution changes, data gaps and uncertainty than is common for other continents.
Using a recently published software suite that enables researchers to make well-posed colour choices, we present a set of colour maps that are suited to the display of Antarctic geophysics data and models. These colour maps consider human perception, and hence maximise the chance of feature discovery within a given datasets, and also minimise the possibility of a mistaken inference due to artefacts of the display process. We also show some workflows that provide an exemplar of the use enhanced graphics capability such as opacity that enable the better management of patchy coverage. We also provide exemplars of visualisation techniques and colour optimisation for rapid display and exploration of volumetric data.
We hope that our colourmaps will find wide usage within Antarctic Sciences, and related disciplines. We also anticipate that wider use of enhanced capability with opacity will help researchers to progress knowledge discovery, finding insights from their data, in the case of resolution challenges and analysis of multiple datasets that are commonly encountered in Antarctic research.

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The field of linear velocities and movements of the Earth's crust in the Penola Strait - Lemaire Channel fault area (West Antarctica)

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Based on the results of 5 cycles of periodic static GNSS campaigns conducted on geodynamic monitoring polygon of the Penola Strait- Lemaire Channel fault area recent local geodynamic processes during 2003-2019 were identified. The vectors of horizontal and vertical movements of the geodynamic polygon are determined in the work and their scheme is constructed. Based on the determined average linear velocities of vertical movements, the field of their spatial distribution in the fault area was constructed. As a result of the analysis of velocity distribution of the vertical movements, the area of subsidence was identified. Based on the determined average linear velocities of the horizontal movements, the values of the dilatation velocity, which characterizes the relative expansion or compression of the territory, as well as the value of total shear, which characterizes the horizontal heterogeneity of the deformed area, were calculated, and the field of their spatial distribution in the area of Penola Strait - Lemaire Channel fault area was constructed. As a result of the distribution analysis of the territory's dilatation velocities, the zones of extreme compression and expansion values were revealed, indicating increased geodynamic activity of the region. As a result of the analysis of the distribution of values of the total shear, it is confirmed that the studied region is horizontally heterogeneous. Based on the analysis, a new kinematic fault area model was developed. The assumption was made that the specified fault transgressive characterized by a combination of strike-slip and thrust.

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Improved regional and global gravity field modelling to provide a consistent grid of terrestrial gravity anomalies in Antarctica for further application in geosciences

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To infer both precise satellite-only as well as high-resolution combined Earth gravity field models (EGM) terrestrial gravity data are needed globally and, especially, in the polar regions. For Antarctica, a first consistently compiled gravity anomaly grid was published by Scheinert et al. 2016, which, however, did not cover the entire Antarctic continent. Since then, new data have been acquired, especially over the GOCE polar gap region (Forsberg et al. 2017). Now, in a joint project funded by the German Research Foundation, we aim to re-process all available ground-based and airborne gravity data in Antarctica in order to come up both with an improved grid compilation and an enhanced global model. We will discuss the different steps of processing, including the cross-validation of individual surveys with a combined high-resolution EGM based on satellite and topographic data (Zingerle et al. 2019), and the least-squares collocation for the combination of the different datasets. The improved Antarctica gravity anomaly grid will have a resolution of 5x5 km². It will be used for further studies in Antarctic geosciences, e.g. to infer by inverse methods bedrock topography and depth of the Mohorovicic discontinuity. We will discuss how such analyses will benefit from the improved gravity field solution.

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Geomorphological comparison of the seafloor volcanism in the Bransfield Basin volcanoes in other Back-Arc Basin settings

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The Bransfield Strait is a seismically active back-arc basin between the Antarctic Peninsula and the South Shetland Islands. Subduction slowed in the region around four million years ago; however, back-arc volcanism and extension continued throughout the basin. The extensional rifting and local volcanism are believed to mark the transition to seafloor spreading within the Bransfield Basin. BRAVOSEIS (BRAnsfield VOlcano SEISmology) is an international effort focused on the understanding of the submarine volcanoes and complex tectonic regime in the Bransfield Strait. During research cruises conducted by the BRAVOSEIS Project in 2019 and 2020, aboard the R/V Sarmiento de Gamboa and BIO Hespérides, we collected multibeam soundings, gravity and magnetic measurements, and multi-channel seismic data around two central locations: Orca Volcano, located near King George Island, and Humpback (Edifice A), located near Livingston Island. Over Orca Volcano, we collected data along 21 profiles with lengths of 20 to 30 km, and over Edifice A data, we collected 16 profiles. Interpretation of the bathymetry shows significant differences between the morphology of these two volcanic features. Our study will use high-resolution publicly-available bathymetry data along with data collected during the BRAVOSEIS expeditions to compare the volcanic features in the Bransfield Basin with each other, and with volcanic edifices along the rift axis of similar marine basins undergoing active back-arc volcanism and extension. Our comparison between the seafloor geomorphology observed in areas with similar tectonic settings will inform our interpretations of the complex tectonics in the Bransfield Basin.

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Crustal composition and its thermal and geological implications of continental Antarctica: progress from receiver functions

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The chemical composition of the Antarctic crust has been difficult to assess since over 98% of the continent is covered by ice-sheets, yet it is necessary for investigating the geological history and sub-ice geotherms. Seismological tools provide in-direct measurements to the physical attributes (e.g., seismic properties) of the crust and uppermost mantle. In this presentation, we report the result from a systematic investigation to the crustal Poisson's ratios across the continent using the receiver function technique. We show that an improved 2-layer H-k stacking to the receiver functions can provide more accurate estimates of the Poisson's ratio for the crystalline crust. After its application to all seismic stations deployed in Antarctica, a general trend emerges in which lower Poisson's ratios are found beneath the tectonically active West Antarctica, while the central and East Antarctic show higher Poisson's ratios. More importantly, we show that comprehensive seismic properties (Vs from surface waves and Poisson's ratio) together with petrologic databases can determine the chemical composition (i.e., the silica content) of the crust beneath each station, quantitatively with error estimates. The measured crustal composition has important thermal and geological implications. For instance, a more granitic crust is found beneath the Polar Sub-glacial Basins, indicative of either a more chemically evolved crust or an Archean crust with Tonalite-trondhjemite-granodiorite composition. The high SiO_2 near the S. Pole also provides insights to the anomalously high geothermal heat flux, which is indicated by the thermal profile and the existence of sub-ice melting.

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The HiPSMI project: High Precision Supercooling Measurement Instrument for supercooling measurements under ice shelves

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The oceans beneath Antarctic ice shelves are the least measured waters on Earth. Beneath the Antarctic sea ice and ice shelves, sea water is often colder than its freezing point temperature, yet still liquid. Such water is called “supercooled” sea water. Snap-freezing of supercooled sea water and small free-floating ice crystals known as “frazil” are fundamental obstacles to obtaining high-precision measurements of key ocean parameters needed for climate research. In the project “Supercooling measurements under ice shelves”, we are working to overcome this obstacle by working as an international collaborative team (New Zealand, USA and Norway) to design and construct a new novel instrument; the High Precision Supercooling Measurement Instrument (“HiPSMI”). HiPSMI has been designed and built over the last year, and is optimised for harsh Antarctic ocean conditions and installed into an innovative, modular underwater robot, “Icefin”. HiPSMI includes high precision temperature and pressure sensors and a pumped electrical conductivity sensor, configured for supercooling measurements with a frazil melting unit. In addition, Icefin will have on-board un-pumped electrical conductivity sensors, possibly including nanotechnology sensors, to allow comparisons with HiPSMI. Observations will be made beneath the sea ice and McMurdo Ice Shelf, Antarctica in October and November 2020. We will determine the influence of frazil crystals on measurements of in situ supercooling. The measurements, in conjunction with numerical modelling and laboratory work, will revolutionise our understanding of supercooled waters by providing a high-precision, observational-based indicator for future climate observations beneath the vast cold cavity ice shelves of Antarctica.

990

Gravity and Magnetics Results from a Marine Geophysics Survey of Orca Volcano in the Bransfield Strait, Antarctica

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The Bransfield Strait, a seismically active extensional rift between the Antarctic Peninsula and the South Shetland Islands. The region is characterized by subaerial volcanism at several locations, most recently the eruptions at Deception Island in 1967-1970, and multiple prior marine surveys provide extensive morphological and petrological evidence for submarine volcanism. As part of the BRAVOSEIS project, an international effort focused on the seismological research of submarine volcanoes and rift dynamics in the Bransfield Strait, we used the R/V Sarmiento de Gamboa during January-February 2019 to collected multibeam soundings, gravity and magnetic measurements, and multi-channel seismic data along 21 profiles with lengths of 20 to 30 km spaced 500 m apart over Orca volcano and 11 profiles with lengths of 20 to 30 km spaced 1 km apart over Humpback Volcano. Analysis includes a geomorphological interpretation of the bathymetry, the construction of maps of gravity and magnetic anomalies, and the processing of seismic sections across the caldera. The bathymetry data from Orca Volcano are consistent with recent motions on both inward and outward dipping ring faults within the caldera. We will present intersecting 2D model profiles comparing the distribution of crustal densities, magnetic structure and underlying mantle densities for Orca and Humpback Volcanoes. This work is supported with funding from NSF Office of Polar Programs and the Spanish Polar Committee.

739

Aeromagnetic data reveal broad basement structures under the Ross Ice Shelf, Antarctica

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Deconvolution of aeromagnetic data from ROSETTA-Ice and Operation Ice Bridge was used to estimate the top of the magnetic sources in the crust beneath the Ross Ice Shelf (RIS). The resulting solutions were filtered to match points of known basement depth from seismic surveys on the RIS and in the Ross Sea, then interpolated to produce the first view of the sub-RIS basement surface. The basement surface reveals large scale features that we interpret as sediment filled structural troughs and basement highs formed during opening of the West Antarctica Rift System. The southward continuation of the Central High, a basement feature identified from marine seismic surveys and DSDP drilling in the Ross Sea, is evident. It spatially coincides with the tectonic boundary between West Antarctica and East Antarctica and separates two sectors that have contrasting densities and seabed depths (Tinto et al. 2019). The gravity-derived bathymetry model for the eastern RIS region shows areas of shallow seabed that may inhibit ocean circulation to critical grounding zones of the RIS along the Siple Coast. In aid of accurate modeling of ocean circulation, the basement surface can be used to refine the bathymetry model further by introducing crustal density variations across the sediment-basement interface. Future work will investigate the resulting differences in the bathymetry model with the inclusion of the basement surface.

1650

L-band sounding of the Greenland and Antarctic ice sheets

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An L-band radar system has been built to measure ice thickness, basal conditions and melt rates of ice shelves in Greenland and Antarctica. The Remote Sensing Center at the University of Alabama has successfully mapped deep layers of ice sheets in Greenland and Antarctica using VHF and UHF radar systems. A new system, operating from 1.2-1.4 GHz across eight channels, has been built and operated in Greenland and again in Antarctica during the 2019-2020 Austral summer near Dome Concordia. As a part of a multi-radar deployment, this L-band radar sounder system was installed in a PistenBully vehicle with an eight-element antenna array being pulled behind the system on a makeshift sled. After having successfully sounded the bed in Greenland, initial quick-look data suggests that the bed has been sounded in Antarctica using L-band for the first time. This paper will discuss the overall design of the system as well as the signal processing considerations for the associated data. It will also present preliminary results showing the successful sounding of the bed near the Dome Concordia research station.

1136

An adaptive sampling approach for optimizing radar sounder flight paths for use in mass conservation models of bed topography

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Mass conservation is a highly effective technique for interpolating sparse radar sounder measurements over fast-flowing areas. In areas with multiple radar sounder flight lines, fitting an approximately mass-conserving bed profile to fixed measurement points can be framed as an optimization problem. Ideally, mass conservation and measured bed elevation constraints can be simultaneously satisfied, however this is not generally the case due to measurement errors and simplified models of unobserved ice dynamics. By comparing model-data misfit to known uncertainties in the input measurements, the probable impact of model error can be assessed. When the error exceeds that plausibly attributed to measurement uncertainty, that suggests a need for more data to reduce the measurement uncertainty and either resolve the potential model misfit or provide hard evidence for the origin of the model error.

A simple algorithm is developed using real-time mass conservation modelling to dynamically update a flight path for an airborne radar sounding system to achieve a specified level of uncertainty in ice thickness by continuously collecting new flight lines in optimized locations until the threshold is met. This algorithm could be applied to future autonomous data collection platforms to assess when the collected measurements are sufficient and to avoid large variations in the resulting model uncertainty. Applying this dynamic sampling strategy can minimize the need to repeat field campaigns when the data collected is found later to be insufficient.

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Assessing satellite and helicopter-borne radar for observing crevasses in Antarctica

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Crevasses can provide valuable information about the glacial system, current and past, but they also pose significant risks to operating safely and effectively in glaciated areas. Radar has a long legacy of application to ice and snow environments, including the identification of buried crevasses. Over 2019-20 Austral summer we conducted operational trials of a helicopter-mounted GPR system for detecting and mapping crevasses out of Davis Station, Antarctica. In conjunction with each GPR survey performed, a number of supporting ground-based snow measurements were made, collecting data on snow moisture, snow density and pH and EC of melted snow samples. At crevassed sites we also measured the snow bridge thickness and crevasse width to ground truth spatial information derived from the GPR data.

Data from these test flights is also being used in conjunction with high resolution X-band satellite radar images to test their capacity to identify crevassed regions. These satellite images, acquired by the German Space Agency's TerraSAR-X instrument, in combination with the radar data, have the potential to significantly enhance the future identification of safe field sites, and this validation will be a world-leading test of their use in this context. The combined data sets allow us to investigate the potential and limitations of each radar method over a range of glacial site characteristics and provide significantly improved dimensional and locational accuracy.

429

Characterising the ice sheet - bedrock interface zone using seismic waveform modelling: challenges and technique development.

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The character of the ice sheet - bedrock interface zone potentially yields insight into the tectonic evolution of regions such as East Antarctica, and also has significant impact on the response of the overlying ice sheet to global change. While seismic techniques are well established in understanding hidden structure, relatively thin layers at depth present a challenge for techniques based on arrival time.

In this presentation we explore the potential of waveform modelling techniques to infer the character of structure at the base of ice sheets. Parameters of interest include sediment thickness, saturation, composition, grain size, the composition of the bedrock beneath, and whether any water present is in a frozen or liquid state. With light-logistic data acquisition in remote areas of East Antarctica in mind, we simulate seismic waveforms recorded using a small number of stations over plausible sub-ice structures such as flat layers, channels and eskers. We use either small active sources, or ambient seismic wavefield configurations.

Using pre-existing and newly-written numerical codes for waveform simulation, running on GPU-accelerated architecture, we explore the advantages and disadvantages of available techniques. We find that new implementations of a spectral (Fourier) method and a finite difference method have practical advantages for the characterisation of ice sheet basal structures. In particular, the new methods are suitable for rapidly scanning over a range of interfacial parameter values, allowing determination of the sensitivity of the system to small variations in these parameters.

1569

Integrating englacial reflectors between the the Amundsen Sea and Ross Sea Embayment of West Antarctica.

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The Antarchitecture project is a multinational initiative to construct a cohesive englacial stratigraphy for the Antarctic Ice Sheet, using ice penetrating radar. This compilation will require integrating data from radar systems with differing center frequencies, bandwidths and processing approaches, from multiple institutions and surveys with different science goals. Early work on such inter-comparisons has focused on Dome C in East Antarctica. Here we discuss progress on performing these inter-comparisons in West Antarctica, in the vicinity of Thwaites Glacier, the Siple Coast Ice Streams, and Pine Island Glacier. Using oil industry seismic packages, UTIG and the University of Edinburgh have performed extensive mapping of key glacial horizons through the catchments of Thwaites Glacier (with HiCARS), the Ross Sea Embayment (with the SOAR incoherent system) and Pine Island Glacier (PASIN). UTIG has mapped out six key horizons and connected them to the WAIS and Byrd ice cores, and performed a Bayesian analysis on the uncertainty in the age of four of these horizons. In Marie Byrd Land, we find evidence of complex englacial structures related to subaerial volcanism. Through flight lines that were shared between the surveys, we assess the correspondence between the three stratigraphies.

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SESSION 18

BIRDS AND MARINE MAMMALS

Mark Hindell
Yan Ropert-Coudert, Ryan Reisinger

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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In-situ observations of an intact natural whale fall in Palmer Deep, Western Antarctic Peninsula

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In early 2017, an intact whale fall was discovered by personned submersible in Palmer Deep, off Anvers Island along the Western Antarctic Peninsula. The skeleton of a ~ 9m Antarctic minke whale (Balaenoptera bonaerensis) lay on a steeply sloped, muddy substrate at 963m and was observed to be in the later enrichment-opportunist stage of decomposition. The skeleton remained largely articulated, with several caudal vertebrae scattered upslope and a disarticulated jaw and baleen plates downslope. The community of organisms present was filmed in HD for approximately two hours; observed fauna included representatives of at least ten phyla, and comprised at least ten OTUs directly associated with the bones (polychaetes Osedax and Vigtorniella, plus several amphipod species, being most abundant), and a further 15 OTUs considered incidental (the fish Notolepis coatesi and salp Salpa thompsoni most abundant). The observed faunal distribution suggests patterns consistent with planted whale falls and supports the oil gradient hypothesis. This discovery represents the highest-latitude natural whale fall reported to date.

1491

Using aerial survey data to understand Adélie penguin metapopulation dynamics in the Ross Sea

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The Adélie penguin (Pygoscelis adeliae) is an indicator species used to detect and monitor the effects of environmental change on Antarctic marine ecosystems. Since the early 1980s, New Zealand has conducted an annual aerial census of Adélie penguins along the western edge of the Ross Sea from Ross Island to Cape Adare. Data are submitted to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Ecosystem Monitoring Programme (CEMP). Population dynamics within a colony are the result of the demographic processes of survivorship, recruitment and dispersal among neighbouring colonies. We use the annual census data to develop a metapopulation model to assess how these processes are influenced by sea ice conditions. We hypothesise that sea ice conditions in their over-winter range influence survivorship and the overall number of breeding pairs in the Ross Sea. October-November ice cover in the vicinity of a colony should influence breeding-colony access, return rates and dispersal among neighbouring colonies. That is, if extensive ice prohibits access to a colony, individuals may immigrate to neighbouring colonies. Sea ice cover during the breeding season (December-January) should influence prey abundance and Adélie penguin recruitment rates. Understanding these spatiotemporal dynamics is critical to detecting and describing ecosystem changes, and predicting long-term effects of climate change on Adélie penguin populations in the Ross Sea.

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Fin whale (Balaenoptera physalus quoyi) distribution in Antarctic and Australian waters using passive acoustic monitoring

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The fin whale has a global distribution with all populations listed as vulnerable, yet little is known about the present-day distribution, movements and abundance of the Southern Hemisphere sub-species, B.physalus quoyi. This study uses passive acoustic monitoring as a tool to identify the seasonal distribution of fin whales as they disperse from Antarctic to Australian waters. Sampling was conducted from 8 sites in Antarctic and Australian waters from 2002-2018, providing a total of 35 annual records. Acoustic presence in Antarctic waters, indicates a yearly pattern of presence of fin whales at the southern Kerguelen plateau from February-June, with a mean of 61.3 calling days and 41,512.3 sounds detected per year. At the Dumont d'Urville site, acoustic presence was identified from February-May with a mean of 37 calling days and 8,798.5 sounds detected per year. In comparison, the Casey site had a seasonal pattern of presence from February-May with a mean of 5.6 calling days and 2,049.7 sounds detected per year; with no fin whale presence detected in 2018. Arrival of fin whales in Australian waters occurred first on the west coast, at the Cape Leeuwin site, which had a decadal pattern of presence from May-October, with the earliest detection on the 12th of April, 2008. On Australia's east coast, at the Tasmania site, fin whale presence was identified from May-October. The consistent seasonal trends in presence, number of calling days and detections provides valuable information on the distribution and migratory patterns of this Southern Hemisphere sub-species of fin whale.

1473

Chinstrap penguin increases foraging distance in response to tick parasitization

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The tick Ixodes uriae has been recently reported as present in the three species of pygoscelis penguins distributed along the Antarctic Peninsula. Their effects on the penguins have been described reducing survival, transmitting blood parasites and diseases and affecting their immune response. However, tick effects on the performance capability of the penguins have never been studied. The distribution and abundance of ticks in the chinstrap penguin rookery of Vapour Col in Deception island, South Shetlands, offers the opportunity to study their potential effect on the foraging performance of penguins. Foraging behaviour data were obtained by means of GPS and TDR (time-depth recorder) devices attached during five days on the penguins. We recorded data on mean duration of the foraging trip, mean foraging trip distance, maximum trip distance, mean number of dives, mean total time diving, mean dive duration and maximum depth. We also studied whether ticks could affect food intake or the foraging habitats used by the penguins at sea by means of stable isotopes of N and C analyses. Our results show that penguins inhabiting the area with high density of ticks travel more distance and use more pelagic habitats measured by carbon stable isotope than penguins living in the area with low density of ticks. No effects were detected in diving behaviour or duration of the foraging trip. No differences were found in the diet measured by N stable isotope.

877

Genetic and toxicological status of southern elephant seals (Mirounga leonina) around Antarctic waters with emphasis on the colony at Isla 25 de Mayo (King George Island), South Shetland Islands, Antarctic Peninsula

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The southern elephant seal (SES) (Mirounga leonina) has a circumpolar distribution, breeding mainly on sub-Antarctic islands, and making long trips between breeding colonies, molting locations and foraging areas, exposing to pollutants such as mercury (Hg). Although individuals show fidelity to a set of established breeding colonies, their migratory habits may allow long-range gene flow. To assess the Hg concentrations and genetic status of SES on the colony at Isla 25 de Mayo (KGI; 62º15’S, 58º39’W), skin samples from free-ranging individuals (n=60) were collected using a remote biopsy dart during 2015-2016 austral summer. Toxicological results indicated that SES Hg concentrations ranged between 142-1,915 ng/g (mean=730 ng/g, SD=388), values higher than reported for humpback whales skin in western Antarctic Peninsula (mean=35 ng/g, SD=3.7, n=14), due likely to feeding ecology (whales prey on krill whereas SES consume fish and squid). Regarding genetics, the mitochondrial DNA Control-Region results showed a high haplotype diversity, and indicated that SES from KGI are closely related with individuals from Elephant Island, Livingston Island, and Islas Malvinas (Falkland Islands), but maintained restricted genetic flow with individuals from Macquarie Island and the now extinct colony from Victoria Land Coast. Microsatellite analyses confirmed high genetic diversity. Parentage analyses identified 2% of individuals in the sample as mother-offspring, 16% as full/half siblings and 82% as unrelated individuals. These results agree with previous findings of long-distance genetic dispersal mediated mainly by SES males. Due to large feeding range, SES can be a good sentinel to continue pollutant monitoring in Antarctic and sub-Antarctic waters.

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Occurrence of marine mammals along the Southeastern Pacific Ocean and the western Antarctic Peninsula, observed on board of the "ARC 20 de Julio" vessel during Colombian Scientific Expeditions to Antarctica

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The Marine Mammal Monitoring Program at the Colombian Antarctic Program has conducted marine mammal survey on board the "ARC 20 de Julio", a Colombian Navy vessel, with the goal of assessing occurrence patterns of marine mammal species along the Southeastern Pacific Ocean (SPO) and the Southern Ocean (SO), following a transect from Panama to the western Antarctic Peninsula. A total of 1,745h (38,785km) of visual observation effort were conducted along around 92,709km of distance traveled during four expeditions (2014-2015 to 2018-2019 austral summers). A total of 917 marine mammal sightings were recorded, 701 of which were identified to the species level, representing 29 species (SO=5; ESP=20; both=4). Encounter rates (ER), assessed separately for the SPO and SO, were calculated by groups observed per 100h and 1,000km, showing the highest ER to the South American fur seal and humpback whale for the SPO and SO, respectively. Univariate kernel analyses were conducted to explore the influence of Chlorophyll-a concentration and bathymetry over the most common marine mammal species distribution. These analyses suggested that species frequency is higher within productive areas. Regarding bathymetry, the South American fur seal, bottlenose dolphin, dusky dolphin, and killer whale seem to be more frequent in waters less than 1,000m in depth, in contrast to the common dolphin, blue and sperm whales. Further survey and monitoring are needed to effectively assess abundance and distributional pattern as well as the potential impacts of anthropogenic activities and climate change on marine mammals' distribution in the SPO and the Antarctic Peninsula.

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The Humpback Whale Sentinel Program Reveals 2017 as an Anomalous Year in the Eastern Antarctic Sea-ice Ecosystem

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In 2017, the world observed some of the most dramatic changes recorded in Antarctica in modern history. July 2017 saw 10% of the Larsen C ice-shelf cleave off as a massive iceberg. The year continued with the appearance of a 300,000 m2 polynya in the winter sea-ice off east Antarctica, and summer sea-ice coverage was the lowest ever recorded, 27% below the mean annual minimum. The Humpback Whale Sentinel Program (HWSP) is a long-term, circum-Antarctic biomonitoring program for surveillance of the Antarctic sea-ice ecosystem. It is designed to complement existing sentinel programs under the Convention for the Conservation of Antarctic Marine Living Resources
Ecosystem Monitoring Program, and produce open source data for Antarctic and cetacean research communities. HWSP conducts annual monitoring of five distinct southern hemisphere humpback whale populations, equating to 'eyes' on 80% of the circum-Antarctic region. The longest record of annual sentinel parameter measurements (12-years) is available for the eastern Australian migrating stock (E1). Temporal analysis of sentinel parameters of the E1 population revealed 2017 to be an outlier. Blubber tissues revealed new dietary signatures, not previously observed; animals were in poorer nutritional state, and the migratory cohort showed a greater than average skew towards males within precisely comparable time windows; potentially indicating missed, delayed or incomplete migration among reproductive females as an energy conserving strategy. Finally, the stranding incidence of juveniles and calves was significantly elevated. Results presented here lend strength to the use of migratory baleen whales for capturing present-day changes within the remote Antarctic ecosystem.

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Movements and diet of Weddell seals in the southern Weddell Sea

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Satellite tracking and stable carbon (δ13C) and nitrogen (δ15N) isotope data were used to assess seasonal movements and trophic position of five Weddell seals (Leptonychotes weddellii) in the southern Weddell Sea in 2018.

The seals travelled greatest overall distances in autumn and winter. Distances were shorter in spring and summer when seals spent a greater proportion of time hauled out on sea ice. Total distances travelled per day varied between sexes and over seasons. The seals' haul out behaviour switched between primarily nocturnal (autumn and winter) to diurnal patterns (summer and spring). Location data indicated that polynyas were frequented more often in winter and autumn, and less often in spring although the marginal ice edges of the polynyas were still used to haul out.

Average δ13C value where higher in seals sampled in the southern Weddell Sea (-21.43 ‰) compared to those in the Ross Sea (-24.3 ‰ – -22.5‰) and similar to seals sampled in the Western Antarctic Peninsula (-22.4‰ – -20.1‰). This highlights the seals' preference for foraging near productive coastal zones and over enriched benthic communities. Weddell seals in our study area consume similar prey types as revealed by average δ15N values of 13.85 ‰, which are similar to those of Weddell seals in other areas of Antarctica.

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Foraging behavior of lactating Antarctic fur seals at the extreme edge of their breeding distribution

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At its most southerly breeding range, the Antarctic fur seal operates at its highest field metabolic rate in an environment challenging the physiological limits for energy acquisition. Currently, we have little understanding on how edge colonies, already coping with high environmental variability, may deal with additional variation contributed by specific atmospheric events. By using a combination of diet estimates and biologging we evaluated how additional environmental variability (2014/15 El Niño year compared to non-El Niño years) may affect the behavior of colonies already operating near their metabolic limit. Foraging behavior was compared between all years using 18 variables that represent: trip duration, recovery time (time ashore and at the surface), diving effort, spatial distribution and diet. We found differences in proportion of each prey consumed, a reduction in recovery time after each trip (shorter time ashore) and more trips to oceanic waters and the shelf break. No differences were found in diving effort or diving variables indicating individuals may be operating at their physiological maximum. Although prey consumed changed during the breeding season in all years, the proportions of each prey consumed differed. Overall, females prioritize changes on where and what to eat over how they dive. Behavioral plasticity is an evolutionary advantage in the face of rapid environmental change, but it may have its limits. Those limits can be best understood in populations breeding constantly in the fast lane of life.

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Foraging ecology of Antarctic Minke whales (Balaenoptera bonarensis) elucidated from fine-scale kinematic data and new methods of determining prey distribution from fisheries acoustic data

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Antarctic minkes are prevalent in the West Antarctic Peninsula, though they are not as frequently observed as other cetaceans since they usually forage near the ice edges deep in bays, and little is known of their specific foraging habits and habitat use. In 2018 and 2019 we deployed 33 suction cup accelerometer and video tags in concert with acoustic prey mapping in Andvord and Paradise Bays at ~ 64°S, 62°W. Feeding behavior ranged from feeding at the surface to deeper feeding around 200 m. Combined accelerometer and video data revealed that foraging and filtering was extremely rapid, with inter-lunge-intervals as low as 9 seconds and filtering of the entire 4-5 m3 buccal cavity in less than 5 seconds- a rate of approximately 1 ton of water per second. Video data also revealed sequential, simultaneous foraging of up to 5 animals in a group over the course of several dives. Simultaneous prey-mapping from boats trailing immediately behind tagged whales reveals that whales return to patches that they have previously foraged in, and analysis of the distribution of prey densities reveals that if minkes forage in the densest parts of patches the size of their foraging dives, they can improve their foraging efficiency by greater than a factor of 3. The unique prey conditions in the deep, icy parts of Antarctic bays were likely a niche unexploited by larger baleen whales prior to whaling, and the need to exploit these conditions likely helped drive the speciation of Antarctic minke whales.

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The Cytological, Microbiological Evaluation of Ocular Surface Samples Taken from Penguin Species of the Antarctic Peninsula II: Immunohistochemical and Phylogenetic analysis

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The study aims to assess the efficiency and usability of ocular surface cytology, in terms of cellular and microbiological diagnosis, in penguins belonging to the Pygoscelis genus. For examination of cytological samples, impression and brush cytology techniques were used. Cell specimens collected by brush cytology were used for the evaluation of cell morphology and the presence of bacteria, fungi after undergoing cytospin centrifugation. Cytological changes were evaluated under light microscopy according to Nelson's grading system. Impression cytology was used as a simple method for the sampling and counting of conjunctival goblet cells. Due to the adhesion capability of the sampling device, impression cytology were used to collection of the most superficially located cells on the ocular surface. Corneoconjunctival surface epithelial cells and sporadic inflammatory cell infiltrations were observed. High rates of goblet cells were noted in some of the preparations. Microscopic examination of preparations revealed superficial, intermediate and basal epithelial cells organized in layers. Degenerate epithelial cells, fibrine, neutrophil leukocyte, bacteria and fungi, cellular debris and mucus were detected on eyes. Psychrobacter Genusu Corynebacterium and Corynebacterium sphenisci were mostly isolated on the ocular surface.Genus Psychrobacter is found in different environments.Most of the Psychrobacter species studied were isolated from cold and saline environments. Global environmental change affecting pollution, increased connectivity and pathogens is likely to cause future diseases in this region.Oppurtunistic fungal infections can facilitate traumatic injuries to the ocular tissues.Strong IL-4 supports its reactivity.

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Temporal and ontogenetic variation in trophic ecology of crabeater seal (Lobodon carcinophaga) from the east Antarctic Peninsula

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We analysed stable isotopic composition in dentine Growth Layers Groups (GLGs) – in canines from mummified (~100 yr) seals from Marambio Island. GAMMs (General Aditive Mixed Models) were run to understand the ontogenetic variation in $\delta^{15}N$ and $\delta^{13}C$ values. Additionally, we analysed whisker segments of mummified and actual crabeater seals to estimate their isotopic niche area. Yearlings showed wider isotopic niche area, higher $\delta^{15}N$ and lower $\delta^{13}C$ than subadults and adults. The latter showed no differences in isotopic values. GAMMs showed significant effects of GLGs in the isotopic values, with an increase in $\delta^{13}C$ from GLG-1 to GLG-5/6 and a decrease in $\delta^{15}N$ from GLG-1 to GLG-3. Higher $\delta^{15}N$ in yearlings may be influenced by lactation as well as tissue catabolism during the post-weaning fast. After 5-6 years (sexual maturity) values tend to stabilize. These trends probably reflect differences in the foraging pattern of younger individuals or the effect of high growth rate on isotopic discrimination values between prey and predator tissues. Actual seals showed wider isotopic niche areas and higher $\delta^{15}N$ than mummified seals. No significant differences were found for $\delta^{13}C$. Changes in baseline could explain these $\delta^{15}N$ differences. We provide novel information on the trophic ecology of crabeaters from the eastern Antarctic Peninsula.

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Variability in tissue-specific isotopic discrimination factors (Δ13C and Δ15N) between Antarctic krill Euphausia superba and free-ranging Pygoscelis penguins

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For top consumers in marine environments, isotopic discrimination factors (Δ13C and Δ15N) between food and consumers' tissues are expected to be similar amongst related species. However, the few studies conducted in the laboratory indicate a large variability among species, which should be potentially higher in free-ranging animals. Here, we test for differences in tissue-specific Δ13C and Δ15N values of two wild penguin species (Chinstrap Pygoscelis antarctica and Gentoo P. papua) breeding in sympatry at Livingston Island (Antarctica). A total of 41 adults and 28 chicks, and food items comprised exclusively by Antarctic krill (Euphausia superba), were sampled for stable isotope analyses. Overall, Δ13C values varied between -1.8 and 4.0 ‰ and Δ15N values ranged from 1.2 to 6.1 ‰, and these differed between species, tissues and age-classes. While discriminant factors differ between adults of both species only for δ13C values (in feathers and blood), chicks of both related species showed highly distinct Δ13C and Δ15N values in nails and muscle (in feathers differed only in Δ13C). Our results show that discriminant factors can differ substantially between closely related species preying on similar prey, especially in δ13C value. Variation in Δ13C was driven by species, tissue and age-class, while variation in Δ15N was mostly driven by tissue type. Discriminant factors may be associated to physiological and/or stress factors which may fluctuate in the wild, and this was particularly evident on chicks. This study highlights the use of diet specialized species on the determination of discriminant factors in the wild.

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Use of the opportunistic method to study penguin diet: which tissue is best for stable isotope analysis?

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Tissues from penguin carcasses are increasingly used for isotopic analysis of diet. This method is known as “opportunistic sampling” since chick carcasses are commonly found around active colonies and can be easily sampled without disturbing nesting penguins. However, depending on the tissue sampled, there could be variable results and/or differences in fractionation. Here, we investigated isotopic signatures (δ13C and δ15N) and variability among four tissues (feather, skin, toenail, and bone) collected from fledgling-period chick carcasses of three pygoscelid penguin species at 25 de Mayo/King George Island, South Shetland Islands, Antarctic Peninsula, during austral summer 2017-2018. We accounted for annual and geographic variation in isotope values by limiting our collection to one region and one season. A total of 20-30 carcasses per species was sampled at active colonies of Adélie (Pygoscelis adeliae) and Gentoo (P. papua) penguins at Stranger Point, and from Chinstrap penguins (P. antarctica) at the nearby Barton Peninsula in February 2018. Isotopic signatures varied among tissues due to fractionation, but all tissues revealed dietary differences among the species. Skin had the highest variability and was the least reliable tissue for isotope analysis while toenails had the lowest variability. Comparison of isotopic values between two bones (tibiotarsus and coracoid) showed no significant differences suggesting that sampling of any major skeletal element will provide similar results when the same element is not available from all carcasses sampled. Our results allow more informed opportunistic sampling to accurately estimate and compare penguin diet among species and between ancient and active colonies.

1163

Using a dynamic energy balance IBM to assess drivers of change in the population of elephant seals at Macquarie Island

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Southern elephant seals are predatory, capital breeding, marine mammals with a circumpolar distribution. The population on Macquarie Island has been a part of longitudinal studies since 1949 and is in decline at an average rate of -1.46% per year. The exact drivers behind the population decline are unknown, and while migration has been discounted, competing hypotheses postulate increase in female mortality, decrease in recruitment, breeding success, environmental changes at foraging grounds and yearling survival.

We use a dynamic energy balance individual based model (DEB-IBM) to evaluate four hypotheses regarding the observed population decline on Macquarie Island through implementing scenarios of i) climate variability ii) reduction of yearling survival iii) reduction in the fecundity of mothers, and iv) density dependence in the model. The modelled population trajectory for all scenarios (except a reduction in fecundity of mothers) closely followed the observed trend in the decline of southern elephant seals at Macquarie Island.

The underlying emergent properties of the population and individuals were reasonably realistic. An overall weakness in the model was a poor representation of interannual variability, as compared to the observations. Thus, although the model produced interesting emergent behaviour of individuals and the overall population, none of the scenarios in isolation could explain the driver behind the observed population decline. We conclude that it is likely that a combination of drivers has resulted in population change at Macquarie Island.

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Foraging Behavior and Physiology of the Leopard Seal in the Antarctic Peninsula

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The Antarctic Peninsula is one of the most rapidly changing habitats in the world. To better understand the ability of the leopard seal, an apex predator in the Antarctic ecosystem, to cope with a changing environment, we examined the foraging behavior and habitat utilization of leopard seals using satellite telemetry over two years. We deployed a total of 21 satellite-linked tracking devices on 4 adult males, 17 adult females, and one juvenile female leopard seal on Cape Shirreff Livingston Island, Antarctica during April-May 2018 and 2019. Mean mass was 404 kg and ranged from 147 to 540 kg. Seals predominately remained in the South Shetland Islands moving between other penguin and fur seal colonies throughout the South Shetland Islands. In 2018 two female seals transited well to the northeast, with one stopping at South Georgia Island. Seals made short shallow dives with a mean depth of 29 ± 7 sd meters and a duration of 3.6 ± 0.5 sd min. The single deepest dive was 720 m and the longest was 10.1 minutes. Physiological parameters were taken on 9 individuals and were consistent with a shallow aerobic diver, with a blood volume of 134 ± 5.2 sd ml/kg. Hematocrit ranged from 44 – 56 with a mean of 51 ± 4 sd. Myoglobin concentrations in the locomotor muscles 6 animals ranged between 44.9 ± 1.4 se mg/gr for Longissimus dorsi and 32.9 ± 0.8 se for pectoralis muscle.

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An empirical investigation into self-awareness of Antarctican penguins: An application of Modified Mirror Test (MMT)

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Penguins are special type of flightless birds mostly available in the southern hemisphere, and one of the very few species living in the earth for over 60+ million years. Penguins are social birds-feed, swim and nest in discrete homogeneous groups in ice-sea zones of Antarctica. They exhibit a spectacular example for cooperative behaviour by having a well-organised social system with defined family ties. Well-orchestrated group behaviour enables them to meet the challenges of extreme environments of Antarctica, albeit with a primitive brain structure. All these characteristics have made them quite special in the evolutionary history. Self-awareness and Self-recognition qualities may be regarded as essential pre-requisites towards formation and maintenance of rookeries (=penguin groups). It generates a cooperative framework to withstand extremes of Antarctica. Self-awareness ability is one of the building blocks for the development of robust penguin societies. Their social and awareness network appears to be strong and vibrant.

The present study was undertaken to test self-recognition of Antarctican Adelie penguins (Pygoscelis adelia) as a building block of their society. The test was conducted during the 39th Indian expedition to Antarctica in the month of January-February 2020. The empirical investigation using a newly devised Modified Mirror Test (MMT) confirmed that penguins are self-aware about themselves in individual and group level. The uniqueness of the experiment which was improved over the pioneering work on self-recognition experiment on Chimpanzees and pigeons done by G.G.Gallup (1968 & 1970) and Skinner (1981) will be presented and discussed in the SCAR open science conference 2020.

1578

Humpback whales in the Southern Hemisphere – need for transdisciplinary research to understand species response to changing climate

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Humpback whales are an iconic cetacean species present in all major oceans. Nearly hunt to extinction, the species' Southern Hemisphere populations have recovered in recent decades. Its annual migration between feeding and breeding grounds represents one of the largest animal migrations on earth, but also exposes them to a wide variety of environmental conditions. The majority of published studies on this subject list sea surface temperature (SST) and bathymetry as the most important environmental parameters followed by chlorophyll a, salinity, currents, and distance offshore.
Very limited research has been done to implement the effects of climate change into humpback whale life histories but is essential for estimating the future distribution and movements of this species.
To try and understand how environmental parameters vary in time and space under climate change scenarios (1.5, 2- and 4-degree Celsius of global warming), here we defined five key system modules: ocean biogeochemistry and physics; ocean and atmosphere interactions; whale biology; and anthropogenic impact. We use coupled mechanistic models at appropriate length- and timescales that integrate, based on the importance of environmental drivers, key physical, biogeochemical, biological, and ecological system parameters. Outputs of these models consequently feed into behavioral (agent-based) models that simulate humpback whale movements through time and space under current and future climate scenarios. Given the high ecosystem and economic value of this species, we believe our approach advances international whaling conservation efforts and may be advanced to other marine species. To follow up on the project visit www.whalesandclimate.org

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Long term foraging areas of top predators: how much tracking data do we need?

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Home ranges of terrestrial mammals are often delimited by physical barriers, while those of marine mammals are generally limited by biological processes including feeding, migration and breeding. This theoretically provides opportunity to use long-term marine mammal tracking data in detecting consequences of climate change in the absence of physical barriers. Identifying stability in important areas of habitat use may allow investigation of change in relation to variables indicative of climate change. Southern elephant seals (SES) from Marion Island have seemingly unlimited choice of pelagic space to exploit. We ask how many years of constant tracking data are needed to identify a core area of habitat use for the population? From a comprehensive database of 20 410 locations collected from 1999 through 2012; 6 309 at sea foraging locations were identified using a switching state-space model. Areas of high use were identified using kernel density estimators. We calculated overlap in annual foraging areas with Bhattacharyya's Affinity (BA) index. A kernel with all locations was used as a baseline to measure the variance in overlap with annual kernels. The mean difference in overlap was 0.25 (±0.14), with greatest difference in overlap being 63% in 2000 and smallest difference in overlap being 0.06% in 2008. Our final habitat kernel was more representative of female SES habitat use (BA=0.93, 57% of locations, n=75) than of male SES habitat use (BA=0.84, 42% of locations, n=48). We suggest that our current database of tracking locations of SES from Marion Island encompasses 75% of SES habitat use.

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Penguin Microbes

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Within all higher organisms, lives a thriving ecosystem of microorganisms including, bacteria, viruses and fungi. These microorganisms are crucial for an animal's health, nutrition and physiology, playing an important role in digestion, protection against harmful pathogens, secretion and synthesis of essential vitamins, minerals and amino acids. So what microbes colonise the penguin gut and what functional pathways are involved? Previous studies using amplicon sequencing have assisted in the profiling of the microbial community within different penguin species. However, amplicon sequencing is restricted to a specific target region (bacteria, virus, and parasite) and due to the short read length is often unable to identify organisms to the species and genus level. This study used shotgun metagenomics to sequence the microbial community (including viruses) and the associated functional pathways of king, gentoo and macaroni penguins. Similar to previous studies species specific differences were observed between the three species. In addition a number of known pathogenic organisms were identified. Over 2,600 functional pathways were identified in the study with significant differences observed between species in approximately 2,000 pathways, with many of these pathways being present in macaroni penguins and absent in king and gentoo penguins

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So_Predbase – An unprecedented database of archival and tracking data from a key Southern Ocean migrator

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Understanding the effects of climate change on Southern Ocean ecosystems, including changes in marine resources, biodiversity and ecosystem plasticity, requires data on trophodynamics. Yet, basic biological information, paramount for quantifying and predicting whole ecosystem changes is not available for species across all trophic levels in vast regions of the Southern Ocean. Marine predators provide an integrated summary of the status of the rarely sampled organisms down the food chain and are effective tools to monitor changes in bioaccumulated contaminants in remote oceanic environments. Here, we present the framework for a new database housing an unprecedented ten-year+ tracking and archival tissue dataset for a key Southern Ocean marine predator, the Antarctic fur seal (Arctocephalus gazella) across large spatial scales to meet the critical datagaps described above. Breeding adult female Antarctic fur seals at Marion Island were geo-tagged between February and April 2008-2019, in each year which is toward the end of lactation and before dispersal from breeding sites prior to commencing their winter migration. Sampling of archival tissue collection (whiskers and blood samples) also occurred at this time and upon the return of the females. SO_PREDBASE will be comprised of stable isotope (δ13C and δ15N) data on whiskers and blood, trace metals on whiskers and tracking data collected from GLS loggers on a decadal time scale. As an archival tissue, the whiskers will help us to encode longitudinal records of those biochemical features to infer temporal changes in foraging plasticity and physiological status which can potentially be attributed to climate change.

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Underwater Homing Tactics of Weddell Seals in the Antarctic Shore-Fast Sea Ice Environment

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Most activities of Weddell seals occur during dives that extend hundreds to thousands of meters and require the seals to hold their breath for 20 minutes or more. In the fast-ice environment, breathing holes are scarce. Consequently, seals must return to a previous breathing hole or locate a new one to avoid drowning; how they navigate underwater with such precision is not known. This study used field experiments to test multiple hypotheses concerning the sensory cues and tactics Weddell seals employ to navigate underwater in this challenging environment, with special attention to their possible use of geomagnetic cues. An archival data logger was fitted to 10 adult seals, which were released at three locations that differed in the orientation of the geomagnetic field, and allowed to perform voluntary dives. Analysis of three dimensional dive tracks demonstrated that outbound paths of dives progressively increased in distance from the breathing hole. Seals returned home on remarkably straight paths, or they traveled directly to a frequented route then turned straight toward home. These findings are consistent with piloting by landmarks. Seventy-five percent of the frequented routes were directly below known linear disturbances in the snow on the top of the ice, indicating that the landmarks were overhead visual cues. They were able to do so during both daylight and surface twilight, presumably due to exceptional visual sensitivity in low light environments. We did not find evidence that seals navigated by geomagnetic or hydrodynamic cues under these conditions.

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Long-Term Passive Acoustics Monitoring of the Ross Sea Marine Protected Area

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The Ross Sea region of the Southern Ocean is one of the most isolated and pristine environment on the planet and it is protected by the world's largest marine protected area (MPA). Commercial fishery for Atlantic toothfish also takes place in the Ross Sea, and uncertainties exist on its effects on the overall ecosystem, especially its interaction with top predators.

NIWA is leading a New Zealand programme to study the conservation value of the Ross Sea region MPA. Under this programme, we deployed three passive acoustics recorders in the Ross Sea to: 1) study the seasonal occurrence of sperm whales; and 2) understand ecological connectivity between this top predator and toothfish. We aim at understanding the potential effects of commercial toothfish fisheries on sperm whales in the Ross Sea region. Our passive acoustic research in the Ross Sea also provides an opportunity to study its soundscape and its modifications under future climate variability/change.

Data were collected recording for 342 seconds at a sampling rate of 48 kHz, then 64 seconds at a sampling rate of 125 kHz, and then to turn off for 12 minutes. This duty cycle permitted to record for an entire year, from summer 2018 to summer 2019. The recorders were refurbished and redeployed in summer 2019, and we are planning another instrument swap in 2021.

Data revealed the presence of baleen whales, the foraging of sperm whales and other odontocetes, as wells as temporal presence of leopard and Weddell seals under the ice.

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Modelled mid-trophic pelagic prey fields improve understanding of marine predator foraging behaviour

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For oceanic predators, foraging behaviour is influenced by processes that shape the distribution of prey over multiple scales. We use a spatiotemporally resolved simulation model to describe difficult-to-observe mid-trophic prey distribution within the Southern Ocean, and demonstrate insights that this modelled prey field provides into the foraging behaviour of a widely distributed marine predator, the southern elephant seal.
From a five-year simulation of prey biomass, we computed climatologies of mean prey biomass (average prey conditions) and prey biomass variability (meso-scale variability). We also compiled spatially gridded metrics of seal density and diving behaviour from 13 years of tracking data. We statistically modelled these metrics as non-linear functions of prey biomass (both mean and variability) and used these to predict seal distribution and behaviour. Our predictions were consistent with observations, indicating that seals aggregate in regions of high mesoscale activity where eddies concentrate prey. Here, seals dived deeper and spent less time hunting, likely targeting deep but profitable prey patches. Seals generally avoided areas of low eddy activity where prey was likely dispersed. Most seals foraged south of the Subantarctic Front, despite north of the front exhibiting consistently high simulated prey biomasses. This emphasises the importance of mesoscale prey biomass variability relative to regionally high mean biomass. Our work demonstrates the value of coupling mechanistic representations of prey biomass with predator observations to provide insight into how biophysical processes combine to shape species distributions. This will be important for robust prediction of species' responses to future system change.

1203

Unravelling Isoscapes at the Base of the Antarctic Ecosystem for Robust Dietary Evaluation of Humpback Whales

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Isoscapes of Southern Ocean marine ecosystems are not uniform, varying spatially and temporally. Euphausiids in the Ross and Amundsen seas have significantly higher $\delta^{15}N$ values but lower $\delta^{13}C$ values than zooplankton from the Western Antarctic Peninsula even though phytoplankton $\delta^{15}N$ and $\delta^{13}C$ values do not differ significantly among these regions. Phytoplankton $\delta^{15}N$ values only vary temporally. Understanding and accounting for such spatial and temporal variations in isoscapes at the base of the Antarctic ecosystem, is particularly important when assessing the diet of high-fidelity Antarctic krill (Euphausia superba) consumers like southern hemisphere humpback whales (Megaptera novaeangliae), to avoid interpretation bias of results. Here, we analysed Antarctic krill sampled in different Southern Ocean regions, plus skin biopsy samples of five distinct southern hemisphere humpback whale breeding stocks to assesses if spatial differences in Antarctic krill $\delta^{13}C$ and $\delta^{15}N$ isoscapes match spatial differences in humpback whale $\delta^{13}C$ and $\delta^{15}N$ isoscapes. Krill samples were collected in the austral summer preceding winter biopsy sampling, ensuring a temporal within-year match. As each southern hemisphere humpback whale breeding stock is thought to utilise distinct Antarctic feeding grounds, we hypothesised that the diet of the breeding stocks would reflect krill isotopic profiles from their feeding ground. Evaluating inter-population variability in isotopic profiles, with prey isoscapes in the Antarctic feeding grounds allows us to refine conclusions about the diet of humpback whales and provide supporting evidence for feeding ground locations for the individual breeding stocks.

1201

The effects of lipids in stable isotope analysis (13C and 15N) of Southern hemisphere humpback whale blubber and skin

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$\delta^{13}C$ and $\delta^{15}N$ stable isotope values in blubber and skin are widely used to study the diet of free-ranging cetaceans. Blubber has a higher lipid content than skin, which can introduce bias in $\delta^{13}C$ values as lipids are enriched in ^{12}C causing a decrease in bulk tissue $^{13}C/^{12}C$. Therefore, it is imperative to assess which tissue provides more reliable results for stable isotope analyses. Thus far, isotopic differences between both tissues have only been investigated for northern hemisphere humpback whales. They are known to have a broader diet than their southern hemisphere counterparts, which feed mostly on Antarctic krill. $\delta^{13}C$ and $\delta^{15}N$ values were determined for lipid-extracted blubber, and duplicate bulk and lipid-extracted skin biopsy samples of southern hemisphere humpback whales using a SERCON EA-Hydra 20-20 isotope ratio mass-spectrometer system. C:N ratios of lipid-extracted were within the same range of 3.0 – 3.3 as C:N ratios of northern hemisphere humpback whales, while bulk skin and lipid-extracted blubber showed higher C:N ratios. Both $\delta^{13}C$ and $\delta^{15}N$ values of lipid-extracted skin increased significantly compared to bulk skin. While the increase of $\delta^{13}C$ in lipid-extracted blubber and skin was expected, $\delta^{15}N$ values of skin also increased significantly and unpredictably after lipid extraction. Considering this, for diet inferences, we recommend that lipid-extracted skin is used for $\delta^{13}C$ values and that bulk skin tissue is used for $\delta^{15}N$ values. Any application of these values should further take into account the faster turnover of skin compared to lipid stores, and hence the temporal reference to diet.

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Long-term monitoring reveals divergent population trends for six seabird species in the Maritime Antarctic

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Fildes Peninsula and Ardley Island, King George Island, South Shetland Islands, represent one of the largest ice-free areas in the Maritime Antarctic. The region is characterized by a high biodiversity and is a reproduction site for fourteen bird species. Based on seabird monitoring data collected between 1979/80 and 2019/20 divergent population trends could be detected. While Adélie and chinstrap penguin populations in the area have declined considerably and have now stabilized at a low level, the breeding pair number of gentoo penguins showed a substantial growth and turned the colony on Ardley Island into the biggest colony of this species in the Antarctic. The local population of southern giant petrels was negatively affected by human activities, particularly by the establishment of several new Antarctic stations in the 1980s. After observed nest site shifts towards areas with less anthropogenic disturbance several formerly abandoned colonies were reoccupied and the overall trend for this species is now positive. The breeding pair number of kelp gulls showed considerable variation and declined slightly during the study period. In contrast, the population of cape petrels declined dramatically and almost completely disappeared in the area. The contrary seabird population trends can is be attributed to a divergent reaction to a variety of environmental factors. Our long-term monitoring data set represents an exceptional high value as it contributes to the knowledge of the seabird population development in the WAP area.

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Environmental DNA as a tool for monitoring Antarctic vertebrates

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Environmental DNA (eDNA) is any DNA shed into the environment by an organism. eDNA surveys are a useful tool for detecting species that are scarce, elusive or cryptic as they don't rely on sightings and can detect multiple species in a single sample. Though eDNA surveys have been successful in other environments, the method has not been broadly used to study Antarctic vertebrates. I will discuss the potential of eDNA as a tool for detecting Antarctic vertebrates and touch on the advantages and challenges of using eDNA to identify and monitor species in remote locations. I will introduce our pilot study on detecting Weddell seal (Leptonychotes weddellii) DNA in snow samples, collected from the Turtle Rock breeding colony in Erebus Bay, and discuss the optimisation of methods at each step in the eDNA sequencing procedure, from snow collection to DNA extraction to downstream lab analyses. The aim of our research is to take this work from our lab, to the ice.
With rapidly advancing technology, eDNA surveys in Antarctica are becoming increasingly feasible. They are non-invasive, cost-efficient and can lead to larger sample sizes. This is important in Antarctica where challenging environments can make even large vertebrates difficult to find, an example being crabeater seals (Lobodon carcinophagus) which live on the Pack Ice. Thus, eDNA surveys have great potential as monitoring and conservation tool in Antarctica.

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Whales return to the epicentre of whaling? Preliminary results from the 2020 cetacean survey at South Georgia/Islas Georgias del Sur

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Over 170,000 whales were killed in the sub-Antarctic waters of South Georgia/Islas Georgias del Sur (SG, South Atlantic) from 1904 to 1965. In recent decades, whales are regular summer visitors, with the southern right whale (Eubalaena australis) and humpback whale (Megaptera novaeangliea) most commonly reported. A 23-day cetacean survey was conducted in SG waters during January/February 2020, using directional acoustics and visual surveys to localise whales, and collecting skin biopsies, photo-identifications, and blow samples for microbiome analysis. The survey focussed on southern right whales (SRW), and also collected sightings, photo-identifications and skin biopsies from other species. A total of 1,147.1 nautical miles of visual survey effort was conducted. In total, cetaceans were encountered 540 times, including SRW (10 encounters of 11 individuals), humpback whales (409 encounters, ~790 individuals) and blue whales (Balaenoptera musculus, 38 encounters, ~58 individuals). Two SRW were satellite tagged and their movements subsequently tracked. Photo-identifications and biopsies were collected from SRW (11 and 7 respectively), humpbacks (48 and 17 respectively) and blue whales (25 and 9 respectively). Aerial imagery was collected via Unmanned Aerial Vehicle during four SRW encounters, with three blow samples also collected. Additionally, one faecal sample was collected from one SRW. This was the first expedition to conduct whale surveys along the remote south coast of SG since whaling ended, and overall yielded an unprecedented number of sightings of both blue and humpback whales, suggesting that the waters of SG are again becoming an important summer feeding ground for both species.

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The influence of environmental and social factors on the demography of killer whales (Orcinus orca) at sub-Antarctic Marion Island

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Predator populations have been found to be responsive to bottom-up processes. However, a thorough understanding of the response of marine predators to temporal variations in environmentally driven conditions is lacking. Killer whales, Orcinus orca, are apex marine predators occupying every ocean on the planet but much still remains to be investigated, particularly regarding the population at Marion Island in the southern Ocean. We used single- and multistrata analyses in RMARK on mark-recapture data to investigate the demography and effect of environmental, social and prey covariates on survival of killer whales at Marion Island over a 12 year period (2006-2018). Survival ($\Phi = 0.98$) and population growth ($\lambda = 1.01$) rate were found to be constant with no differences in survival between sex or age classes. Sea surface temperature, the southern oscillation index, fur seal pup numbers and several measures of sociality at time lags (t0 to t-4) did not significantly explain temporal changes in survival. Survival was however significantly explained by southern elephant seal pup numbers at a one year time lag (t-1), Patagonian toothfish fishing effort at a one and two year time lag (t-1 and t-2) and the mean strength of association at a one year time lag (t-1). These results suggest that the survival of killer whales at Marion Island is partly influenced by prey availability and social structure. Social structure may therefore play an important role in killer whale survival during future anthropogenic changes to the environment as a result of climate change.

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Use of space places Southern Giant Petrels as useful monitors of Antarctic Peninsula

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While Antarctic Peninsula (AP) experiences fast environmental change, it is challenging for researchers to cover simultaneously a substantial amount of sensible areas in order to properly monitor those changes. In this study, we show that, by continuously tracking throughout the breeding season individuals from a single population of Southern Giant Petrels SGP (Macronectes giganteus), it is possible to have access to environmental conditions in a large array of habitats along the whole AP. Breeding SGPs engaged on 5 to 15 days long foraging trips across a 5000 kilometers wide area between the Weddell and Bellingshausen seas. SGPs more likely reduced speed below 10 km/h, denoting foraging behavior, in low to intermediary ice cover conditions at land habitat, and in pelagic habitats when ice cover was >75%. SGPs also were more likely to reduce speed nearby penguin colonies in lower ice conditions. We also found evidence of association with glacier edges where Weddell seals (Leptonychotes weddellii) gather to rest. Therefore, tracking SGPs can give researchers access to conditions on a large variety of habitats and regions of the Antarctic Peninsula. A long-term study joining GPS tracking, animal-borne cameras and demography parameters on a small number of colonies should provide us with a large amount of data on distribution and condition of sea ice, glaciers, penguin and seal populations on different spatial and temporal scales.

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Identifying gaps and vulnerabilities for conservation of Southern Oceans' top-predators using zonation spatially explicit models

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The importance of marine protected areas MPAs have become unanimous among scientists. However, global coverage of MPAs is still deficient, particularly in Antarctica, only 0.4% of marine areas is under protection. In this study, I congregated ecological niche models and metrics with spatially explicit models to identify priority areas for conservation of marine top-predators in the southern oceans and identify gaps in the current MPA network. I found a generalized niche overlap of top-predators with fisheries that substantially reduced the ability of spatially explicit models to identify highly important areas and substantially increased extinction risk. Areas of high diversity of top predators were more likely to occur on areas of high vulnerability to fisheries than within current MPAs, indicating that the network fails to cover most of the highly important ecosystems. That is particularly concerning on the northern tip of the Antarctic Peninsula and East Antarctica. The results I found suggest that fishing pressures have been more important in decisions about placing of MPAs than the real needs of protection. Results support the use of reactive protection by prioritizing managing areas under high risk from fishing activities.

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Antarctic icy waters hide some oases for emperor penguins: circumpolar habitat suitability analysis

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Predicting species persistence in the face of climate change requires an understanding of the drivers of species distribution. The emperor penguin's reliance on landfast sea ice is complex: low fast ice extent reduces the availability of breeding sites and may have consequences on food resources, but extensive fast ice causes longer foraging trips for parents and decreases the frequency of food delivered to the chicks. Until the past decade, addressing emperor penguin distribution and habitat has been limited, because continent-wide observations have eluded researchers until recently. Technological developments have enabled the use of satellite imagery to observe emperor penguin colonies and a better characterization of the sea ice habitat at finer spatial scale. Novel algorithms to characterize polynya and the icescape have also been recently developed. Our research aims to determine the habitat suitability of emperor penguin colonies across Antarctica using novel fast ice (fast ice persistence, volatility, month of maximum extent/stability), geomorphology (coastal complexity) and polynya (time-series of polynya openings based on sea ice production at a daily scale) metrics. The analysis was performed using sea icescape data from 2000 to 2018. This research will aid in understanding the mechanisms by which climate change may impact penguins in the realistic ice landscape, by studying the role of fast ice, polynyas and geomorphology on the distribution and persistence of penguin colonies. This has both short to long-term impacts for the conservation of this species by understanding its past and present distribution to better predict their distribution in the future.

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Trends in emperor penguin populations around the entirety of Antarctica

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Recent modelling research has suggested that emperor penguin populations are likely to decline substantially by the end of the 21st century due primarily to sea ice losses caused by climate change, even accounting for their ability to disperse among existing populations. As a fast-ice obligate, there are likely only two refugia for the species in the long-term in the Ross and Weddell Seas. However, because of their inaccessible habitats across the Antarctic coastline, it is impossible to visit colonies concurrently to assess their populations. Here, we used high-resolution satellite imagery (VHR) combined with aerial survey estimates as ground validation, and Bayesian analysis to estimate populations of emperor penguins at colonies around the continent during 2009-2018. Our models included accounting for the effects of satellite platform and intra-seasonal variation at colonies to estimate the breeding population. We found the majority of populations of emperor penguins were either stable or declining over the ten year period, with substantial annual fluctuations in population size at a few locations. Our results further the hypothesis that emperor penguins operate in a metapopulation framework and that changes at larger, regional scales are most biologically relevant. This work is the first empirical evidence of emperor penguin population change at the continent scale over 10 years.

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First census of Weddell seals from space: many fewer than expected

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Weddell seals are fast-ice-obligate, marine predators exhibiting an Antarctic circumpolar distribution that is associated with coastal habitats. Traditional methods of understanding population abundance, which have included shipboard or aerial transects and have been done sporadically beginning in the 1960s, are cost-prohibitive and dangerous. With the advent of high-resolution satellite imagery (VHR), the possibility of detecting seals from space became possible. We combined VHR with citizen science via the web platform Tomnod to do 1) a search-area reduction campaign to determine presence vs. absence along the fast ice, and 2) a tagging campaign to estimate abundance where present. Using new statistical methods and comparing to ground counts within Erebus Bay, Ross Sea to validate our work, we determined, for the first time, a full population census for the Weddell seal during 2010-2011. After correcting for the proportion of seals diving when images are taken, we find that the the 95% confidence interval for the estimated mean indicates that the actual number is <50% of the previously estimated population size of ~800,000 animals. Seals are distributed patchily around the continent with highest regional abundance in the Ross Sea (about 50% of the global population) and lowest abundance in the Amundsen Sea. Given the surprisingly low estimates combined with previous data suggesting seals in the Ross Sea may be declining, we suggest that dramatic action may be required to protect the species from the negative effects of fishing and climate change.

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Fronting up – How important are frontal regions to Southern Ocean migratory predators?

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Multiple definitions of Southern Ocean fronts have emerged over previous decades. This has led to confusion in the biological community on how best to quantify the importance of frontal regions for marine species. One of the definitions incorporates the dynamic features of frontal regions which are critical in establishing correlations with the movements and habitat use of highly mobile and migratory species. In this study we aimed to assess the importance of frontal regions to two highly migratory Southern Ocean marine vertebrates: the surface diving Antarctic fur seal (5-200m) and the deep diving Southern Elephant seal (400-2000m). To do this we sourced tracking data from a long-term time series of Antarctic fur seals tracks during the non-breeding period (SO_PREDBASE) and the MEOP data base of Southern elephant seal tracks. By undertaking this analysis we provide greater understanding on the importance of fronts to the two key Southern Ocean consumers at different vertical, temporal and spatial scales.

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Comparing isotopic niche metrics of Antarctic seals between sites under distinct climate warming conditions

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The Southern Ocean has been particularly vulnerable to global climate change. While the western Antarctic Peninsula (WAP) has suffered significant temperature fluctuations, the eastern AP (EAP) has not yet showed evident signs of disturbance. Yet, little is known about the influence of warming on the ecology of mammals such as crabeater (Lobodon carcinophaga) (CS) and Weddell seals (Leptonychotes weddellii) (WS). We compared species sampled on EAP (Weddell Sea, 6 CS, 4 WS) and WAP (Danco Coast, 13 CS, 14 WS) between 2014-2016 using stable isotopes of whiskers to assess how environmental differences may be shaping habitat use and diet. Mean values were -21.7‰ ($\delta^{13}C$) and 7.0‰ ($\delta^{15}N$) for EAP CS; -23.0‰ ($\delta^{13}C$) and 6.7‰ ($\delta^{15}N$) for WAP CS; -16.4‰ ($\delta^{13}C$) and 14.5‰ ($\delta^{15}N$) for EAP WS, -21.6‰ ($\delta^{13}C$) and 12.7 ‰ ($\delta^{15}N$) for WAP WS. Niche metrics were estimated through Stable Isotope Bayesian Ellipses in R. EAP showed wider isotopic niches for both species (CS: 2.0 vs. 1.1‰², WS: 7.8 vs. 1.4‰²), which showed complete segregation within the isotopic space in both areas. $\delta^{13}C$ and $\delta^{15}N$ range were both larger for the EAP community (7.8-5.3‰ vs. 5.6-1.3‰, respectively), as well as mean distance to centroid (4.7 vs. 2.9‰) and mean nearest neighbor distance (9.5 vs. 5.8‰). All results point to a higher trophic length and diversity of basal resources in the EAP, which can be attributed to a higher environmental stability. Isotopic niche differences between species and sites may be due to the influence of climate on baseline values.

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Development of Diving Capability in Weddell Seal Pups

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Weddell seals (Leptonychotes weddellii) are among the deepest diving seals, and adult Weddell seal dive physiology is relatively well understood. However, little is known about the physiology and development of pups during early nursing and the transition to independence. The aim of this study was to investigate the development of diving capabilities in Weddell seal pups throughout early ontogeny. We calculated total body oxygen stores (TBO2) from blood and muscle sampled longitudinally at 1, 3, 5 and 7 weeks of age. These data were correlated with diving behavior measured with time-depth recorders. We found that Weddell seal pups started (at 1w) with mass-specific TBO2 values of 50.01±4.84 mL O2·kg-1; these mass-specific values declined slightly at 3w and then plateaued for the remainder of the nursing period, similar to what has been reported for other polar species. Muscle contribution to TBO2 increased from 18% for 1-week-olds to 21% in 7-week-old pups. We hypothesized that TBO2 would increase with dive experience rather than simply calendar age, but instead found that mass (r2=0.96) and age (r2=0.89) were more significantly correlated with total TBO2 (P<0.0001) than time spent in water (P=0.006, r2=0.59) or dive duration (P=0.007, r2=0.38). Pups spent the majority of their time in the water near the surface and thus did not likely experience hypoxia. Later exposure to hypoxia combined with diving experience may be the key to the subsequent increases in total TBO2 observed in yearlings and juveniles of this species.

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Antarctic fur seal males: tourists, trouble makers or an appropriate sentinel of the Antarctic marine ecosystem?

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In the Antarctic, predators are often used as marine ecosystem sentinels. The remote and harsh climate of Antarctica has resulted in species being monitored that are accessible during the austral summer and breed on land. This is particularly true along the West Antarctic Peninsula where the fishery for Antarctic krill operates and which is experiencing rapid warming, where breeding Antarctic fur seals and penguins have been used to infer changes in krill availability. However, breeding adults must return periodically to land in order to feed dependent offspring, restricting how much time can be spent at sea. Consequently, breeding and foraging indices derived from care-giving adults of a species will only integrate information over a subset of the marine environment, and therefore inferring changes in prey variability from predator indices may be a flawed conclusion. To highlight this we use data from an unmonitored, unconstrained life history stage of a monitored species; adult male Antarctic fur seals. We present tracking data collected from 18 individuals instrumented at the South Orkney Islands shortly after breeding. Using telemetry data, we demonstrate that the pattern of foraging by adult male Antarctic fur seals overlaps perfectly in time and three-dimensional space with breeding of a species currently monitored (Chinstrap penguins) and the areas used by the fishery. Indices collected from unconstrained predators may be more informative of ecosystem change than those currently used, which do not integrate information across the region of interest and may be subjected to interference competition from other, unmonitored species.

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Temporal patterns of abundance and distribution of marine predators across the Scotia Sea and western Antarctic Peninsula using platforms-of-opportunity

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Estimating the at-sea abundance and distribution of cetaceans and pinnipeds is typically conducted using a line-transect surveying strategy that is often logistically and financially difficult to enact on a frequent and regular basis. Such constraints are likely to limit the opportunity for information-gathering at management-relevant scales in space and time. New spatial modelling techniques that overcome some of the assumptions of old methods, such as random placement of transects, are now well grounded in the scientific literature (e.g., Williams et al. 2006). 'Platforms of opportunity', such as International Association of Antarctic Tour Operators (IAATO) vessels, thus offers a unique opportunity to collect fine-scale (within season) and coarse-scale (between seasons) resolution observational data on the distribution of marine mammals and seabirds, particularly in the Antarctic Peninsula region where the great majority of vessels operate regularly. Here we report on the first season of a new program designed to provide cross-seasonal, interannual estimates of cetacean and seabird abundances throughout the Drake Passage, Scotia Sea and the Straits of the West Antarctic Peninsula. We provide spatiotemporally evolving abundance and distribution estimates of 21 marine mammal and 30 seabird species across five cruises on two ships of opportunity during the 2019/2020 austral summer. We demonstrate that it is feasible to develop a high quality science-based time series of data useful for management and conservation purposes, and outline the roadmap for expanding this time series over the forthcoming years and across a greater number of vessels of opportunity.

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Bathymetry drives foraging location in late chick-rearing Emperor Penguins from Cape Crozier, Ross Sea

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The survival and success of marine predators depends on their ability to locate prey in a heterogeneous environment. To find prey that are patchily distributed, predators need to be able to adjust their foraging behavior depending on the conditions they encounter. Ice conditions and bathymetry have been associated with foraging locations of emperor penguins from Adélie Land and the Mawson coast during chick rearing. We investigated the movement and dive behavior of nine emperor penguins from Cape Crozier in November 2019, the most southern colony in the Ross Sea. Foraging trip duration ranged from 1 – 18 days (mean 11.2 days). Two birds traveled west of Ross Island (~130 km), spending time within 25 km of the continent (~400 m depth). Three birds traveled north between 75-130 km from the colony, and four birds traveled northeast to the Ross Bank (Between 130-300 km maximum distance from colony). All penguins swam over deep waters performing pelagic dives between 100-250 m depths. Seven penguins performed a mix of pelagic dives (usually < 200 m) over depths >500m and benthic dives to depths >350m when near the continent and over Ross Bank. Emperor penguins displayed flexible foraging behavior influenced by bathymetry, potentially targeting different prey during foraging trips depending on location.

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Comparative three-dimensional home ranges of adult male southern elephant seals

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Resource selection studies in ecology are commonly undertaken at a population-level, yet long-term individual-level studies are undoubtedly important. We compared the travelling- and dive behaviour characteristics of 22 adult male southern elephant seals (Mirounga leonina) tracked from King George Island / Isla 25 de Mayo (KGI) at the Antarctic Peninsula, with data obtained from 28 migrations performed by 17 adult males tracked from sub-Antarctic Marion Island (MI). The population-level home ranges of seals were similar in size for their two-dimensional home ranges (95% kernel density estimate: MI = 2.19 million km^2; KGI = 2.1 million km^2). However, Marion Island elephant seals typically performed deeper dives (MI = 605 ± 427 m; KGI = 444 ± 282 m), resulting in substantial differences between the total water volumes used when incorporating dive depths into population-level home range estimates (three-dimensional 95% kernel density estimate: MI = 1.4 million km^3; KGI = 0.67 million km^3). We further investigated the relative influences of population of origin, individual-level behavioural variability, estimated seafloor depths and migration type (i.e. post-moulting vs post-breeding migrations) on the three-dimensional home ranges of study animals. We found no statistically significant support for consistent individual-level differences in three-dimensional home range sizes between populations, but rather that individual-level variability explained most of the data variance, followed by other drivers (e.g. migration time and seafloor depth). These results highlight the need for continued broad-scale long-term individual-level monitoring in this species to inform population-level resource use and habitat requirements.

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Gentoo penguin population dynamics and the CEMP time-lapse camera validation experiment at Galindez Island, Antarctic Peninsula

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Gentoo (Pygoscelis papua) penguin colony population behavior/dynamics have been studied during 2018/19 and 2019/20 seasons. The detailed observation of bird arrival, nesting, hatch, and crèche has been provided in two colonies at the GAI CEMP site at Galindez Island nearby the Vernadsky station. We inform on the results of the visual survey of the penguin population and penguin count. During two seasons the winterers-biologists at Vernadsky station provided continuous observations every day/every five days of Gentoo's GBV and GPP sites. The results of visual observations of penguin population changes are discussed. The three seasons of the data validation experiment have been provided for pictures from time-lapse cameras of the CEMP camera monitoring project of CCAMLR are discussed. During 2017/18–2019/20 seasons, biologists-winterers at GAI CEMP site, provided daily observations of 15 Gentoo nests chosen in the three monitoring sites GBW, GPP1, and GPP2, simultaneously with automatic time-lapse cameras picturing. The results of visual observations have been compared with data from camera pictures. The comparison of lay, hatch, and crèche dates was undertaken. The preliminary results exhibit a reasonable correspondence within 0-3 days between visual observations and time-lapse camera data for three seasons. The standard deviation for each event varies from ±1 to ±3 days for control nests. However, the time delay in 1 to 3 days between the registered dates by the camera and visual observations was recorded. This delay should be taken into account when the event dates from camera data analyzed without correspondent visual observations.

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Results of the Pygoscelis penguin colonies survey in the Argentine Islands (Antarctic Peninsula) area

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The Gentoo (Pygoscelis papua) colonies survey in the area nearby the Vernadsky Antarctic station has been provided during the 2019/20 breeding season. The Gentoo penguins are the most populated species in the area from Booth Island in the north to Berthelot Islands in the south. The nesting of Gentoo penguins at Galindez Island was noted first in 1998 when in that time the southernmost colony of this penguin specie was attempted to form. The first successful Gentoo colony at Galindez Island was registered in 2007 with 26 nesting pairs. Since 2007 this colony exhibits a fast-growing penguin population. According to the 2019/20 count, the number of Gentoo nests at Galindez Island increased to about 1200 nests. The expansion of the Gentoo population to the south has also been confirmed by the appearance of the Gentoo colony at the shore near Demaria Mountain, where the 2019/20 count confirms about 590 pairs. The Gentoo colony at the Green Island (Berthelot Islands), which is possibly the southernmost studied site of the nesting habitat of this specie, is double in two years to about 40 nesting pairs according to 2019/20 count. Therefore, the Green Island colony exhibit an increase in numbers and an expansion of the Gentoo penguin population to the south. These results are also considered for modeling the distribution of the Gentoo penguin population in the area.

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The characteristics of krill swarms in relation to the distribution of blue, fin, and humpback whales off east Antarctica

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The 2019 ENRICH Voyage (Euphausiids and Nutrient Recycling in Cetacean Hotspots) was a marine biological research voyage conducted in the Dumont D'Urville Sea from 19 January – 5 March 2019. One of the key aims of the multidisciplinary science programme was to better understand the relationship between baleen whales and their main prey, Antarctic krill (Euphausia superba). During the voyage visual and passive acoustic observations were used to detect and locate whales, while active acoustics were used to detect krill swarms. Blue whales (Balaenoptera musculus intermedia) were detected and located predominantly via passive acoustic monitoring (acoustic detections at 238/295 listening stations; 26 sightings). Fin whales (B. physalus) were detected more-or-less evenly via acoustic and visual methods (150/295 listening stations; 124 sightings), and humpback whales (Megaptera novaeangliae) were detected and located predominantly via visual observations (105 listening stations; 201 sightings). 1,679 swarms of Antarctic krill were detected along the ship's track using active acoustics, and their characteristics measured. Characteristics of krill swarms were then used to model the presence and density of Antarctic blue, fin and humpback whales. We address the challenges of using whale and krill observations that span vastly different spatial and temporal scales, and we discuss preliminary results from our models in the context of recovery of whale populations, and management of krill fisheries.

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Advances in long-term underwater passive acoustic monitoring around Antarctica

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Since 2004 the Australian Antarctic Division has collected over 100,000 hours of underwater sound recordings in Southern Ocean off East Antarctica. Recordings were made by mooring autonomous acoustic recorders at deep water sites along annual resupply routes to Australia's three stations in East Antarctica, and many sites have now yielded several consecutive and/or non-consecutive years of data. While early data were collected to listen for critically endangered Antarctic blue and endangered fin whales, over the years the number of species recorded has increased in step with improvements in hardware and digital storage. Since 2013, acoustic recorders have been able to provide information on the presence and behaviour of many Antarctic top predators including: crabeater, leopard, Ross, and weddell seals, sperm whales, killer whales, and all species of high-latitude, Southern Ocean baleen whales (blue, fin, humpback, Antarctic minke, sei, and southern right). Here we present a brief overview of this rich, long-term acoustic dataset including samples of the many weird and wonderful sounds that we typically detect. Additionally, we present high-level analysis of the seasonality of the loudest, most prominent sounds. Blue and fin whales were prominent late-summer through autumn; Antarctic minke whales from winter into early spring; crabeater and leopard seals were prominent in spring; and wind, wave, and ice noise was prominent late spring to mid-summer. This long-term biological and environmental monitoring programme is part of the Southern Ocean Hydrophone Network (SOHN), an international project of both the IWC-Southern Ocean Research Partnership and the Southern Ocean Observing System (SOOS).

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Observing penguin breeding phenology by time-lapse cameras at Ardley Island (South Shetland Islands)

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The breeding phenology and breeding success of seabirds are important indicators to describe the state of the marine ecosystem, as is reflected in CCAMLR Standard Methods A2 and A9. However, the collection of such data is time-consuming and, in many remote locations, logistically limited and always depends on weather conditions. Stationary cameras offer the opportunity to observe wildlife continuously and require much less effort in the field. Since 2016, we operate remote cameras in the penguin colony on Ardley Island (South Shetland Islands, Antarctica). These cameras are used to observe groups of Adélie and gentoo penguins. Our motivation for the installation was to determine the ratio between the number of individuals within the groups and the number of nests. This parameter has proven to be very reliable for the analysis of drone aerial photographs.
In the 2014/15 season, CCAMLR initiated the project "Establishing a CEMP Camera Network in Subarea 48.1". The network members successfully developed methods to extract breeding phenology from the camera data. We applied these methods to extract the parameters peak of egg laying and peak of hatching from the time-lapse cameras on Ardley Island.
For the breeding seasons 2016/17 and 2017/18 we compared the breeding phenology results with those data collected by classical methods in the same colony. We observed that the data obtained with both methods did not differ from each other in case of the local gentoo penguin population and only slightly in case of the Adélie penguin population.

PenguinERA: Ecology, Reproduction and Adaptation for a climate change sentinel. Italian PNRA project for monitoring mid Victoria Land, Ross Sea, Adélie penguin population.

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The Adélie penguin is highly sensitive to ecosystem changes and it is considered an important bio-indicator of ongoing changes in the Southern Ocean. As habitat quality is likely to induce effects on physiology and behavior, PenguinERA project (PNRA 2016 AZ1.11) aimed to integrate the existing long-term monitoring program on this species with the measurement of a series of genetic and physiological parameters. Main activities are carried out by: (i) continuing the long-term monitoring series of data on Adélie penguin in the study area; (ii) identifying a series of proxies of penguin's health status by using non-invasive sampling techniques for measuring blood immune and genetic parameters; iii) integrating proxies with the bio-ecological responses and the genetic parameters, to establish a baseline against which ecosystem changes can be detected. The study area, which involves three Adélie penguin colonies nearby Terra Nova Bay and the Wood Bay (Ross Sea, Antarctica), it is known for its extraordinary biodiversity. PenguinERA would contribute to the understanding of the ecological role of a marine mesopredator such as the Adélie penguin, through the study of its distribution and behavior in relation to the quality of habitat, colony size, evolution and adaptation at the scales of the ecological and climatic processes. Monitoring and conservation studies will allow assessing the additional role of this species as a sentinel of climate changes.

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Climate-mediated environmental variability as a driver of chinstrap penguin foraging behaviour in the Bransfield Strait, West Antarctic Peninsula

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Rapid changes in the climate along the West Antarctic Peninsula (WAP) is having profound effects on associated marine ecosystems. In the northern WAP, warmer temperatures, sharp declines in sea-ice extent and increased wind have been reported. Concerns exist about concomitant changes in the abundance and distribution of Antarctic krill Euphausia superba, a keystone prey resource for upper trophic predators across the region. Chinstrap penguins Pygoscelis antarctica are one of the most abundant krill-dependent predators breeding along the WAP, and population declines in excess of 50 % have suggested changes in the availability of their prey. Yet two synoptic surveys for krill separated by 20 years have shown no change in krill abundance or gross distribution. Given these concerns, understanding how chinstrap penguins forage in different hydrographic regions is an important first step to understand how bottom-up processes may regulate ecosystem dynamics in this region. To determine the foraging behaviour in different hydrographic regimes, we studied the at-sea behaviour of chinstrap penguins on Nelson, Deception and Kopaitic islands in the Bransfield Strait throughout the 2018-19 breeding period. The contrasting hydrographic conditions in the vicinity of each island generated physical gradients across the Bransfield Strait, which resulted in spatial variability in the foraging behaviour of chinstrap penguins between colonies. Our results highlight (1) that mesoscale climate-driven hydrographic variability may modify krill availability to predators foraging in the Bransfield Strait (2) that accounting for mesoscale environmental variability is important if penguins are to be reliable bio-indicators of krill abundance in Ecosystem-Based Fisheries Management.

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Optimisation of Dietary DNA Extraction from Scat samples from Antarctic Top Predators for Metabarcoding

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Food web structure and function of polar ecosystems are dramatically changing due to climate change. Food web regulate mass and energy flow inside and among ecosystems and thus understanding their dynamics has crucial importance. High precision, high coverage dietary analysis tools focused on DNA extracted from scat samples provide a great insight into food web interactions. A non-invasive dietary analysis tool for vertebrates is possible by DNA food metabarcoding in animal scats. Many molecular methods can be employed to retrieve dietary DNA from scats, but many will also recover non-food DNA, which will complicate further PCR and library generation before high throughput sequencing. In order to better understand the role of top predators in Antarctic food webs and elucidate the effects of recent environmental changes, DNA remains in the faecal samples of several top predators (Gentoo Penguin, Chinstrap Penguin, Adelie Penguin, Brown Skua, Weddell Seal, Elephant Seal) of Antarctic Peninsula, sampled during the 2nd and 3rd Turkish Antarctic Expeditions (2018-2019). DNA remains from the samples (>40 per bird species and >15 per seal species) were extracted to be used in metabarcoding to understand the preyed species by the predators. Results gathered from different DNA extraction approaches will be presented to demonstrate how DNA metabarcoding enhances our awareness of the role of the top predators of the Antarctic Peninsula food webs.

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From progesterone in blubber to estimates of pregnancy rates: multi-year analysis of reproductive patterns in Western Antarctic Peninsula humpback whales reveals high recovery potential

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Antarctic humpback whale populations are recovering after intense commercial whaling in the 20th century. Along the Western Antarctic Peninsula (WAP) this recovery is occurring in a rapidly warming environment. To fully assess the recovery of these whales, understanding their current demography and reproductive dynamics is critical. As part of the National Science Foundation's Long Term Ecological Research program, our research group has collected skin and blubber biopsy samples from humpback whales within the nearshore waters of the WAP since 2010. We have assigned a pregnancy state, via blubber progesterone concentrations, to 412 female humpbacks during the austral feeding season between 2010-2018. Blubber progesterone concentrations indicated 62.9% of females sampled across the study were pregnant, with significant variation across all years (low: 36.36% 2010, high: 86.27% 204; $\chi 2 = 32.87$, df = 6, P=0.001). Additionally, we have also found evidence of annual reproduction among females, 57.35% of females accompanied by a calf were pregnant (10.6% of all females sampled). These high pregnancy rates corroborate with the similarly high reproductive rates observed across other Southern Hemisphere humpback populations. To our knowledge, this is one of the first long-term, non-lethal, demographic studies of Antarctic baleen whales and reflects on the demography of whales killed 100 years ago, placing their current population dynamics into the scope of current and future climatic trends. However, the potential response to climate change by humpbacks along the WAP is still unclear and further investigation is needed to better understand long-term population trends to facilitate successful conservation and management.

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Phylogeography and population genetic structure of Snow Petrel populations in east Antarctica

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Seabirds have an extraordinary ability to travel long distances, disperse freely between populations and maintain high levels of gene flow. Ironically, they also exhibit strong philopatry which may lead to pronounced genetic differentiation within and between populations. In this study, we investigated the phylogeography (using mitochondrial cytochrome b sequences) and population genetic structure (using cross-species nuclear microsatellite markers) of the most southerly breeding bird, the snow petrel Pagodroma nivea in Antarctica. The genetic sampling was conducted during three austral summers (2013-14, 2014-15 & 2015-16) under the Indian Antarctic Program at Larsemann hills, Schirmacher oasis and Svarthamaren hills in east Antarctica.
A total of 93 samples were sequenced at mitochondrial cytochrome b region for phylogeographic analysis whereas 142 samples were genotyped for microsatellites. A 792-bp long cytochrome b sequence was obtained from these samples and aligned using MEGAv.6.06. We identified 30 variable sites resulting in 33 haplotypes with three haplotypes were shared between the colonies furthest from each other, Larsemann hills and Svarthamaren hills. Haplotype diversity was higher at all three sites (>0.85). We identified two populations (K =2) from the bayesian individual clustering model in STRUCTURE 2.3. The FST values were found to be low (<0.04) indicating high gene flow between all three colonies. High dispersal ability and long-time spent foraging at sea might be attributed for lower genetic differentiation found between populations. This work lays the foundation for undertaking pan-Antarctic sampling for understanding connectivity amongst spatially disjunct populations of snow petrels.

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Using empirically derived metabolic rates to calculate the aerobic dive limit in developing Weddell seals

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In air-breathing vertebrates, the aerobic dive limit (ADL) is defined by increases in plasma lactate following dives and represents a threshold of aerobic metabolism while diving. Directly measuring ADL involves instrumenting animals with dive recorders and taking post-dive blood samples to measure lactate. However, this is time-consuming and requires access to animals immediately post-dive; thus, ADL is frequently calculated (cADL) using total body oxygen stores (TBO_2) and metabolic rate (MR). While TBO_2 are often directly measured, MR is more difficult to measure and is estimated from data on similar size/age animals or using the allometric relationship between mass and MR described by Kleiber. However, there is a high degree of individual variability in MR and it varies with activity (resting on land vs in water and diving). We measured MR for Weddell seal pups (Leptonychotes weddellii) in air (MRA) and in water (MRW) at 1, 3, 5, and 7 weeks of age. We also estimated MR using 2xKleiber, the typical estimate for pups. We measured TBO_2 in separate individuals, and used these data to estimate cADL. cADL increased with age, whether MRA, MRW, or 2xKleiber was used for the calculation. Using MRW resulted in 18–26% shorter dive durations for each age class (3.8–6.3min) compared with using MRA (5.3–7.8min). Using 2xKleiber overestimated cADL for 1–5-week-old pups by ~10% for MRA, but by 32–39% for MRW. Thus, accounting for conditions when using estimated values is key to arrive at meaningful calculations when empirical measurements are not feasible.

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Development of Thermoregulation in Weddell Seal (Leptonychotes weddellii) Pups

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One of the greatest metabolic costs for endotherms is the energy allocated to thermoregulation. Weddell seal (Leptonychotes weddellii) pups must survive both on ice and in water, two very different thermal environments. This study examined thermal and energetic costs associated with development and thermoregulation in Weddell seal pups. We measured mass-specific metabolic rate in air (MRA) for 8 pups every 2 weeks, from 1–7 weeks old; mass-specific MR in water (MRW) was also measured, beginning at 3 weeks. Additionally, we assessed molt status and estimated body composition. There was a high degree of individual variability in MRA for 1-week-old pups (5.96–13.69 ml O2/min/kg), and with development it generally remained stable or decreased. MRW declined from 3–7 weeks. The difference between MRA and MRW (metabolic equivalence; MRE) also decreased from 3–7 weeks. Molt timing and duration were also variable but 7 of 8 pups were fully molted by 7 weeks. Pups gained mass from 1–5 weeks at a rate of 1.92±0.55 kg/day. The proportion of blubber increased from 1–3 weeks (25% to 38% of body mass), and remained steady from 3–5 weeks (38% to 40% of body mass). By 7 weeks, 6 of 8 pups had weaned and were losing mass. Timing of MRE did not vary with molt status or estimated body composition. Overall, these results indicate Weddell seal pups have developed their thermal capabilities in water by ~5 weeks of age, independent of the amount of lanugo fur or body composition.

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Tracking winter movement of Weddell seals from the western Ross Sea: is overwintering location related to breeding history and success?

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Weddell seals in the Ross Sea are known to feed on Antarctic toothfish, but the details of this predator-prey relationship remain elusive. A commercial fishery for Antarctic toothfish has been operating in the Ross Sea region since 1997, and stock models suggest that fishing has reduced the size of the spawning population of toothfish by about 30% to date. The toothfish spawning population is expected to reduce further to 50% of the unfished level (the CCAMLR fisheries management target) in the next few decades. There is the potential for this change in toothfish abundance to affect Ross Sea Weddell seal populations if, for example, seal breeding success or recovery of seal body mass between seasons depends on consuming toothfish. We present information on research in the south-western Ross Sea over the last 2 seasons to understand the overwintering movement of Weddell seals. We use information on seal movements to investigate locations of feeding and potentially infer feeding on Antarctic toothfish relative to other prey. Seals were satellite tagged in February/March and followed for about 9 months between the end of their moult and their return to breeding sites in McMurdo Sound. We compared over-winter movements by females who had pupped that season and so incurred the large energy cost involved in reproduction, with those who had skipped breeding that year. Overall movements were local but with some females making longer excursions up to 1200 km but still within the Ross Sea region Marine Protected Area.

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Winter diet of gentoo penguins from South Georgia determined using DNA metabarcoding and their overlap with the krill fishery

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The gentoo penguin Pygoscelis papua has a circumpolar distribution, with 26% of the world population residing at South Georgia. Unlike most seabirds breeding at South Georgia these penguins are present year-round and they forage inshore and roost on land at night even during the non-breeding season. The krill fishery around South Georgia operates during winter and this creates potential for the fishery to compete with gentoo penguins for food. This DNA-based diet study is part of a broader project that aims to examine overlaps in the distribution of penguin foraging and krill catches, and the dependence of penguins on krill for food during winter. For diet analysis 600 faecal samples were collected from Cumberland Bay and the Barff Peninsula in South Georgia over the 2018 winter. A universal marker (nuclear 18S) was amplified from samples to obtain broad diet information. Penguin was prevalent in these samples (>85% of the sequence recovered); however, prey DNA sequences were also recovered and were dominated by krill and bony fish. Samples that were positive for these two main prey groups (n=222) were subsequently analysed with group specific mitochondrial DNA primers for higher taxonomic resolution. The DNA results are in broad agreement with previous gentoo penguin diet studies during summer and winter. Satellite tracking data collected in parallel concludes that the overlap of gentoo penguins with the fishery is greater than previously thought, but the amount of spatial overlap and potential for competition is relatively low.

1236

Equilibrium through chaos: Application of game theory in the survival strategy of Antarctican penguins

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Penguins are one of the very few species living in the earth for more than 60 million years, around the time when dinosaurs ruled the earth. They are special type of flightless brids found exclusively in the southern hemisphere. Penguins are social birds – feed, swim and nest in groups and live in extreme cold climate. They also move in groups, which makes them an ideal species to study social biology of animals. Penguins exhibit a well-organized social system having defined family ties. Well-orchestrated group behaviour enables them to meet the challenges of extreme environments of Antarctica, albeit with a primitive brain structure. Penguins huddle together in a group when the temperature plummet. By sticking together they keep themselves warm. This huddling behaviour has been an interesting topic for researchers. Huddling behaviour is highest level of cooperation among the Penguins. Huddling is not motionless. Penguins continuously move from periphery to the centre and vice versa during the huddling. This continuous motion helps them to conserve energy. This conservation of energy is necessary for the Penguins as they fast for long durations.

We are interested in understanding this behaviour. Does game theory help in understanding this huddling phenomenon? We are interested to see if this cooperation among the penguins be achieved as a Nash equilibrium? In our contribution, we develop game theoretic models to study this behaviour and establish the rational foundations behind the cooperative (huddling) behaviour.

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Circumpolar analysis of the foraging areas and habitat use of southern hemisphere humpback whales

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Humpback whales (Megaptera novaeangliae) are globally-distributed baleen whales that show great flexibility in their foraging behaviour and habitat use. Southern Hemisphere populations typically migrate from low latitude overwintering areas to Antarctic foraging areas where they feed on Antarctic krill (Euphausia superba). Following the cessation of commercial whaling, most populations appear to be increasing and humpback whales are now numerous and widespread krill predators that can act as additional sentinels of the vast Southern Ocean system. We compiled existing tracking data from all seven migratory Southern Hemisphere humpback whale populations to identify key circum-Antarctic foraging areas and to better understand the habitat use of these populations in light of the heterogeneous conditions that each population encounters around the Antarctic. We fitted state-space models to satellite tracking data to identity the putative behavioural states of humpback whales. We then related these behavioural states to several oceanographic covariates using generalised additive models, allowing us to characterise the habitat-use of different populations. Our analyses of more than 380 tracks, 2003-2019, totalling some 246,000 location estimates, revealed important foraging areas that reflected areas of high biological productivity. Individuals from different populations encountered very different oceanographic environments and used these environments in distinct ways. This demonstrates the flexible foraging capabilities of this species. The results may have implications for the population trajectories of different populations, given the spatially heterogeneous environmental changes that have been observed and projected in the Southern Ocean.

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Tracking predators to protect Southern Ocean Ecosystems

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In a rapidly changing world, we need to know which areas warrant protection from current and forthcoming threats. This is hard to do objectively in the vast Southern Ocean. However, identifying where predators go also tells us where their prey can be found. If multiple predator species and their diverse prey are found in the same place, then this indicates an area of high ecological significance. We assembled Southern Ocean predator tracking data to produce a database of over 4000 individual animal tracks from 17 species. Statistical spatial models used these data to project the at-sea movements for all known colonies of each predator species across the entire Southern Ocean. These projections were combined across all species to provide an integrated map of those areas important to many different predators. These areas of ecological significance were scattered around the Antarctic continental shelf and in two oceanic regions, one extending from the Antarctic Peninsula into the Scotia Arc, and another surrounding the sub-Antarctic islands in the Southern Indian Ocean. Existing and proposed marine protected areas (MPAs) are mostly within these important habitats, suggesting they are currently in the right places. Yet, when using IPCC climate model projections to account for how areas of important habitat are likely to move by 2100, the same MPAs may not remain perfectly aligned with important predator habitats. Dynamic MPAs are therefore needed to ensure continued protection of Southern Ocean ecosystems and their resources in the face of growing demand by the current and future generations.

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Exploring relationship between foraging trips of chinstrap penguins and krill swarms structures off Nelson Island, South Shetland Islands

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Studying synchronously both the predator and prey spatial distribution is highly difficult, especially in isolated environments such as Antarctica. Usually, tracking is applied separately, on the one hand tracking the predator, identifying their primary foraging areas and timing; and on the other hand tracking the prey, its distribution and abundance. One of the largest chinstrap penguin (Pygoscelis antarcticus) colonies is located at Harmony Point (62.305°S; 59.195°W), Nelson Island. Tracking of chinstrap penguins in the 2019/20 austral summer allowed to identify foraging areas within a 30km from the coast. Penguins concentrated their foraging activities at a mean depth of 226.2 ± 197.0 and median depth of 129.0 meters. Concomitantly to the tracking of chinstrap penguins, we conducted an acoustic survey to study the spatial distribution, vertical structure and density of the Antarctic krill (Euphausia superba) swarms in the foraging area. Dense krill swarms were located mainly between 5 and 150 meters deep in areas closer to the coast, matching the habitat explored by the penguins. These synchronized monitoring provided a better understand of the chinstrap-krill relationship. We proposed that regular acoustic surveys would provide signals of how local krill variability influence the population dynamics of one of the most numerous chinstrap penguin population in the South Shetlands islands.

1425

Winter encounters of humpback whales (Megaptera novaeangliae) near the western coast of the Antarctic Peninsula

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Humpback whales (HW) use waters around the Antarctic Peninsula to feed in summer, before migrating to tropical breeding grounds in winter. However, little is known about winter presence in the region. To study HW distribution patterns during late autumn and winter, we conducted year-round cetacean monitoring at the Ukrainian Antarctic Akademik Vernadsky Station (Argentine Islands). We conducted 17 boat surveys from May 14 to July 24, 2019: 7 cruises in May, 4 in June, and 6 in July. We performed trips when the ice conditions allowed, until access to the open water was blocked by the ice. Most trips occurred in the waters of Penola Strait, French Passage, Petermann, Vedel, and Hovgaard Islands. HW presence during the winter was also logged by daily coastal observations. During the boat cruises we encountered 87 HWs in 41 groups: 18 sightings in May, 17 in June, and 6 in July. The group sizes ranged from 1-6 (Med=2). The primary behavior observed was feeding. HW were predominantly using the area between Petermann, Hovgaard, and Vedel Islands. The last HW encounter happened on July 8, confirmed by coastal observations. Our results indicate the late presence of feeding HW in the region in winter of 2019. It is known that krill move inshore during winter and it is very likely that the whales were taking advantage of ice-free areas during the first part of the winter. We show the ability to monitor winter whale presence in the Antarctic to better understand the impacts of changing conditions.

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Stable isotope values of baleen whales bone samples from Antarctic and Subantarctic whaling stations

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Baleen whales bone samples were collected from two former whaling stations in the Southern Ocean, one at the King George Island (62°04’47’’S, 58°20’47’’W), western Antarctic Peninsula, and another at the subantarctic South Georgia Islands (54°16’54’’S, 36°30’30’’W). We taxonomically identified the samples using bone collagen peptide mass fingerprinting (also known as ZooMS - Zooarchaeology by Mass Spectrometry). Among a total of 120 samples, we matched species identification and stable isotope (δ13C and δ15N) analyses of 44 specimens from Antarctic and 38 from Subantarctic. Three whale species were identified: humpback (Megaptera novaeangliae, n=18), fin (Balaenoptera physalus, n=21) and blue (Balaenoptera musculus, n=43). Fin whales had 13C-enriched values relative to blue whales from the Antarctic ($F=9.3$, $P<0.01$) and Subantarctic ($F=8.5$, $P<0.01$). Fin whales also had 13C-enriched values relative to humpback whales sampled in Subantarctic ($F=8$, $P<0.01$). Regarding δ15N values, fin whales had 15N-enriched values in comparison with blue whales both in Antarctica ($F=11.2$, $P<0.01$) and in Subantarctic ($F=7.5$, $P<0.05$). Fin whales δ15N values significantly differed spatially, with 15N-enriched samples in Antarctica in comparison with Subantarctic ($F=5.5$, $P<0.01$). SIBER (Stable Isotope Bayesian Ellipses in R) did not reveal any significant difference in isotopic niche widths between species ($P=0.75$) and areas ($P=0.30$) investigated, what can be related to the fact that the species are using a broad feeding area. Future comparisons with samples from contemporary (e.g. stranded) specimens can provide novel insights into temporal and spatial changes in baleen whales diet, as a result, for example, of climate variability and concurrent changes in marine ecosystem.

1588

Bird's-eye View: Adélie penguin populations on Ross Island

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Adélie penguin (Pygoscelis adeliae) abundance is a commonly-used indicator of Antarctic marine ecosystem health. Since the early 1980s, New Zealand has conducted an annual census of Adélie penguins in the Ross Sea region, with data submitted to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Ecosystem Monitoring Programme (CEMP). The number of breeding pairs is determined through aerial photography of colonies, and subsequent image processing and penguin counting using semi-autonomous software. Annual changes in the number of breeding pairs can be considered in relation to environmental variables, enabling hypotheses about drivers of population response to change to be tested.

The long-term record of Adélie penguin abundance and distribution in the Ross Sea provides an important baseline for research and monitoring associated with the Ross Sea region Marine Protected Area. It is valuable for assessing ecosystem resilience under changing environmental conditions, investigating the impacts of fishing and invasive species, and analysis of site-specific environmental relationships and species interactions. This poster presents the latest Ross Island Adélie penguin census data, and highlights the value of long-term records of an important Antarctic marine predator.

933

Detection of specific immunoglobulins G (IgG) against canine distemper virus in Antarctic seals

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The first tests to detect the presence of canine distemper virus(CDV) and phocine distemper virus(PDV) antibodies in different species of Antarctic seals were done in the 80s. Current information about diseases in Antarctic wildlife including seals is scarce and fragmented. We analyzed 33 blood serum samples from three Antarctic seals species: Lobodon carcinophaga(CS), Hydrurga leptonyx(LS) and Leptonychotes weddelli(WS), collected at Cierva Cove, Western Antarctic Peninsula. Indirect immunoenzymatic assays (ELISA tests) were performed for the detection of specific IgG against CDV, with a commercial kit INGEZIM MOQUILLO IgG. We found positive serology for 100%LS, 90%WS and negative serology for CS. Since IgG are characteristics of the secondary immune response, the presence of IgG antibodies in LS and WS suggests that they have been probably infected in the past. This infection could be caused by the presence of sled dogs years ago although infections due to seal migratory movements cannot be ruled out as previously suggested. Negative serology for CS could be due to they were not infected or because antibodies were not detected using IgG. Further studies e.g. IgM, against CDV are necessary to strengthen our knowledge and be able to identify recent contact with the virus. Although mass mortality events in Antarctica are highly unusual, considering environmental changes observed in the region due to global change and that alien species and pathogens can be resilient to them, the study of viral infections and associated biosecurity measures become fundamental for conservation prospective and more research on this topic is needed.

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Chinstrap penguin abundance on Elephant Island, South Shetland Islands, Antarctica: Results of the 2020 census

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Over the past decade, considerable effort has been expended to document the population dynamics of the main Pygoscelis spp. penguins on the Antarctic Peninsula, yet critical questions remain. Adélie and gentoo penguin populations have been closely monitored, but the status of chinstrap penguins is not well understood. Chinstrap penguins are difficult to assess because their colonies occur in remote areas, and most have not been directly surveyed for decades. Few populations have sufficient historic or current data to assess whether numbers are increasing, decreasing, or remaining stable. This presents a key gap in our understanding of the Antarctic Peninsula region. Our simplest theories suggest chinstrap penguin populations should be increasing, but limited evidence suggests that they are decreasing sharply in some places while remaining stable in others. Elephant Island is a particularly important site for mapping the front lines of chinstrap penguin decline because colonies occur adjacent to marine areas known to have been negatively impacted by climate change and krill fishing. A thorough census of colonies on Elephant Island has not been conducted for at least 40 years. This paper presents the results of a comprehensive 2020 census of Elephant Island chinstrap penguins, based on ground counts and unmanned aerial vehicles. The findings provide an updated population assessment for the island and surrounding areas, and contribute more broadly to the debate regarding the relative roles of climate change and fishing as drivers of penguin population change in Antarctica.

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Adélie penguin diet at Signy Island, South Orkneys: comparing data from stomach flushing with faecal DNA analysis

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Monitoring variability in predator diets can provide key parameters for understanding and managing the Antarctic Ecosystem. At present, the diets of a number of penguin species are studied as part of the CCAMLR Ecosystem Monitoring Programme (CEMP) using stomach lavage to identify prey composition and mass. Recently, there has been increasing interest in less invasive methods for the analysis of predator diets, and analysing prey DNA in faeces may be a useful approach to complement existing diet monitoring. In order to directly compare these two methods we examined the diet of Adélie penguins Pygoscelis adeliae at Signy Island, South Orkney Islands (60°43'0"S, 45°36'0"W) during crèche (December/January) in 2014/15 and 2015/16. Each method produced a similar pattern of penguin diet, with a shift from almost exclusively krill in 2014/15 to a mixture of fish and krill in 2015/16. Stomach flushing allows some additional information (such as prey size) to be collected, however, faecal prey DNA sampling allowed more comprehensive sampling and DNA markers identified higher taxonomic diversity of fish prey. We discuss the results of this two-year pilot study in the context of the long-term diet dataset (1997-2020) derived using stomach lavage sampling. Faecal DNA analysis provides an opportunity to establish an alternative method for the long-term monitoring of predator diets and could significantly expand the information obtained for ecosystem monitoring.

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Novel insights into habitat use, diving and diet of the elusive Ross seal

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Ross seals (Ommatophoca rossii) are the least studied and scarcest of the Antarctic pinnipeds. Only two studies exist on its at-sea movements: four and eight individuals tracked in the Amundsen and Weddell seas respectively. Diving behaviour has only been recorded for seven individuals and no longitudinal stable isotope data exist. Between 2016 and 2019, we deployed 15 satellite trackers of which seven measured diving behaviour and collected whiskers for bulk-stable isotope analyses from 25 individuals, making this the single largest study on Ross seals to date. Tracking data was combined with the eight animals previously tracked in the Weddell Sea to build the first habitat model for the species. Ross seals travelled away from the Antarctic pack-ice to forage pelagically on myctophid fish and cephalopods. This is reflected in the sequentially sampled bulk stable-isotope data from collected whiskers, with oscillations in δ13C and δ15N values reflecting their south-north movements. During winter, they spend most of their time tracking the marginal sea ice while summer is spent in open water. Ross seals dive deeper, but not longer, during the day presumably following the diel vertical migrations of their preferred prey and haul-out behaviour is influenced by lunar phases. The habitat model shows that sea-surface temperature is the most important indicator of foraging behaviour and they prefer to forage in a very narrow temperature band. This contrasts with suggestions that Ross seals might benefit from climate change due to the receding ice and reduced travel distances required to reach the open water.

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Cephalopod component of the diet of Snares Penguins, Eudyptes robustus, at the Snares Islands, New Zealand, based on historical data from 1986-87

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In the Southern Ocean and adjacent waters, cephalopods are prey to numerous predators, including penguins. The Snares Penguin, Eudyptes robustus, an endemic species from Snares Islands, was used as a local biological sampler to evaluate the cephalopod component of its diet. As historical data on diet are rare for this species, a detailed analysis of the cephalopod component of the diet in the breeding season 1986-87 was carried out and the habitat and trophic level of cephalopods was assessed through stable isotope analyses. The results show that penguins fed on three species: two squids (i.e. Nototodarus sloanii and Onykia ingens) and one octopod species (i.e. Octopus campbelli). Nototodarus sloanii was the most important species in frequency of occurrence and mass, although O. ingens was the most important species by number. The squid species showed similar δ13C values, suggesting an occurrence in similar habitats on the continental shelf of Snares Islands. O. campbelli, showed lower δ13C values, potentially from more offshore waters, and fed on significantly higher trophic level (δ15N) prey when compared to squid species, leading to a completely segregated isotopic niche of this species. Lower diversity and higher sizes of prey were found when compared with more recent data (from the 2000's), suggesting shifts in the distribution and abundance of cephalopods around Snares Islands, probably due to changes in ocean currents and increasing water temperature throughout the years. This study provide essential biogeographic information of cephalopods species and relevant historical information for the conservation of this endemic penguin species.

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Evidence of environmental change in Antarctic marine ecosystems: Penguins, seals and their prey as bio-indicators of change

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Under the context of climate change, the Antarctic region is expected to exhibit considerable changes. We provide scientific evidence of changes in the ecology of top predators, and their prey, in the Antarctic and adjacent regions. Our studies show that Gentoo penguins from South Georgia exhibited different habitat preferences and trophic level according to different oceanographic conditions, similar to Humboldt penguins distributed further north (Xavier et al. 2018a, Chiu-Werner et al. 2019). Moreover, prey switching occurred in the diet of gentoo penguins at South Georgia during Winter, under warmer local conditions switching to their preferred prey Antarctic krill Euphausia superba when sea surface temperatures became colder (late September – early October). This change contributed to the observed demise of penguins and to the consequent later commencement of breeding (2-3 weeks later). Similarly, the foraging ecology of Antarctic fur seals from South Georgia was linked to squid availability, Antarctic krill abundance and regional oceanographic conditions (Abreu et al. 2019). In years of unusually warm oceanographic conditions around South Georgia and low Antarctic krill density, the numbers of the squid Slosarczykovia circumantarctica increased in the diet of Antarctic fur seals when Antarctic fur seals foraged offshore. These research results have been put forward to inform the Antarctic Treaty Parties and develop policies (Hughes et al. 2018) but they are also important for education and outreach initiatives to a wider audience (Xavier et al. 2018b, Xavier et al. 2018c, Roop et al. 2019).

1570

"Stone" can tell us what predators eat and where the diets from: Understanding the role of fish otolith in foraging ecology of predator

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The knowledge of the diets and foraging strategy of land-based and flying predators, particularly in relation to the distribution and abundance of their main prey, is crucial to understanding their role within highly variable marine food webs. On the other hand, by monitoring the diets of such predators a fishery-independent view of stock variability can be obtained. In the Southern Ocean to the south of the Antarctic Convergence 35 species of myctophids are found in the mesopelagic and bathypelagic waters. Of these 35 species, 11 have circumpolar distributions and are mainly widespread from the Antarctic Polar Front zone (APF) to the edge of the Antarctic continental slope. Four species of myctophids (Electrona antarctica, Electrona carlsbergi, Krefftichthys anderssoni, and Gymnoscopelus nicholsi) are distributed circumpolarly and are the important diets of top predators, particularly penguins, seals and flying birds. Otoliths (stone-like calcium carbonate structures) are found beneath the brain of most fish, and can be used to determine more than just age, growth and stock discrimination. The chemical composition of otoliths can also reveal information about the life history of the fish. So otoliths in the stomach of penguins can provide a good proxy to examine the diets and foraging strategy of penguins on myctophid fishes. In this talk, we will use the otoliths of myctophids as examples to investigate the foraging ecology of penguins, seals and flying birds.

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SESSION 19

GENOMIC AND TRANSCRIPTOMIC DIVERSITY OF ANTARCTIC ORGANISM

Jin-Hyoung Kim
Hyoungseok Lee

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Understanding Pseudogymnoascus sp. Response towards Temperature Stress : A Proteomic Approach

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Mass spectrometry (MS)-based proteomics is a powerful tool that has helped researchers to identify and quantify complex protein mixtures in various cells. Under temperature stress, fungi will undergo numerous physiological changes and metabolic modifications for survival. Changes in protein abundances can give an overview of the complex protein response under high and low temperature stress. In this study, Pseudogymnoascus sp. (isolate HND16 R1-1 sp2), a fungus isolated from Arctic soil, was selected as a model organism, in an attempt to provide an overview of how polar fungi respond towards temperature stress via a proteomic approach. Firstly, an optimisation of protein extraction protocols was carried out. Three different chemical extraction methods; 1) TCA-acetone, 2) TCA-acetone-phenol, and 3) phenol-guanidine hydrochloride were used. The quantity and quality of proteins extracted were found to be best when using TCA-acetone extraction. This was demonstrated through total protein content and 1D SDS-PAGE resolution. Subsequently, Pseudogymnoascus sp. was exposed to three different temperatures that represented optimal (15°C), low (5°C) and high (25°C) temperature stress for 5 days and TCA-acetone was used to extract proteins for comparative analysis by 2-dimensional (2D) gel electrophoresis. There were significant differences in the proteome profiles between samples exposed to low and high temperature stress, thus showing the physiological response of Pseudogymnoascus sp. via its proteome. This will be followed by the identification of proteins that change in abundance using tandem mass spectrophotometry.

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Transcriptional Analysis of the Thermal Stress Response In Polar Pseudogymnoascus Spp. Soil Fungi

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Global temperatures are predicted to rise due to climate change. In polar systems, studies to link shifting environmental parameters to physiological response and thus functional activity are lacking in soil fungi. Pseudogymnoascus fungi, commonly isolated from polar soils, have been shown to secrete high levels of extracellular hydrolase enzymes, suggesting a role as important decomposers. In this study, we sought to measure transcriptional changes in these fungi in response to a transient heat. Arctic, Antarctic and temperate strains were cultured at 15°C (ideal growth temperature) for 5 days then transferred to 25°C (heat challenge temperature) for 2 hours. Possible orthologs of Saccharomyces cerevisiae HSP70 and HSP90 genes were identified among available Pseudogymnoascus spp. protein predictions, and their expression following heat treatment was measured by quantitative real-time PCR. Consistently across all strains, two HSP70 homologs and the HSP90 homolog were upregulated, of which two were statistically significant in polar strains. Conversely, one HSP70 homolog was downregulated in all strains, demonstrating functional differences of homologous genes in the HSP70 family. RNAseq analysis of one of the Arctic strains revealed 2,992 differentially expressed genes (DEGs), many of which are involved in pathways of protein synthesis and metabolism. Based on BLASTP search against ESR genes described in the yeasts Saccharomyces cerevisiae and Lachancea kluyveri, 169 out of these DEGs are genes involved in Environmental Stress Response (ESR) (FDR < 0.001). Taken together, our findings suggest that short-term exposure to thermal stress elicits an extensive transcriptional response in Pseudogymnoascus.

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Pseudogymnoascus spp as a potential fungal model for climate change studies

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Fungal species from the genus Pseudogymnoascus are commonly found in soils from temperate and polar regions. Pseudogymnoascus spp are psychrophilic, tolerant to a wide range of stresses, including desiccation, hyper-salinity, solar radiation, and low temperatures by developing functional strategies. Despite the general lack of knowledge on their ecological role, adaptation mechanisms at low temperatures and extreme environments, results from our preliminary studies of environmental stressors on these polar strains have provided some insights. The activation energy (Ea) based on relative growth rates (RGRs) of the fungal isolates vary with nutrient conditions and declined with increasing temperature (Ea was negative). Only certain extracellular hydrolytic enzymes (EHEs) showed activities across the experimental temperature range, indicating trade-off between growth and enzyme activity. As for UVB radiation experiments, exposure to unweight UVB significantly reduced the RGRs and conidia production. Pigments were not simulated under UVB radiation. UVB-induced DNA damage and repair experiments may suggest the nucleotide excision repair (NER) is the primary repair pathway. With these findings, supported with other recent studies, we will justify why Pseudogymnoascus spp is a good fungal model candidate for climate change studies. We will also highlight the importance of filling the knowledge gaps concerning long term data, large scale data, data from multiple simultaneous drivers of change, and the application of genomic, transcriptomic and proteomic approaches.

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Fine scale genetic diversity associated with contrasting thermal tolerances between populations of the Antarctic collembolan, Gomphiocephalus hodgsoni

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Assessing the resilience of Antarctic biota to climate change is integral to predicting the likely impacts of rising temperatures on the survival, diversity and distribution of Antarctic communities. Collembola are key components of terrestrial Antarctic soil systems and are also sensitive to environmental disturbances, making them ideal biological indicators of climate change. The limited dispersal capabilities of Collembola and consequent low levels of gene flow have created highly genetically structured communities which present opportunities to test whether that genetic diversity confers differential survival capabilities. Previous studies have identified two distinct COI lineages of the springtail Gomphiocephalus hodgsoni within Taylor Valley and postulated that the currently dominant upper valley lineage is more cold adapted while the coastal lineage more warm adapted. This project aimed to test this idea by measuring critical thermal maxima and supercooling points of an upper Taylor Valley population and a coastal population from Botany Bay. Our data demonstrate that indeed the coastal population has on average higher upper thermal limits (overall mean: 31.3 ℃, range of means: 28.0-32.9 ℃) compared to the upper valley population (overall mean: 27.2 ℃, range of means: 22.2-31.5 ℃). The coastal population also had on average higher supercooling points, further reinforcing this pattern (coastal mean: -14.3 ℃; upper valley mean: -22.6 ℃). These findings highlight the potential that as temperatures rise warm adapted populations may start to proliferate at the expense of more cold adapted groups leading to overall changes in community structure and a decline in genetic diversity.

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Phylogeny of the gastropod mollusk Nacella concinna and mollusk-associated bacteria from the water area of the Argentine Islands, Graham Land, West Antarctica

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Three morphotypes of the Antarctic limpet Nacella concinna were found in the water area of the Vernadsky Station (Ukraine). The morphotypes were very diverse in their shell surface and coloration. A phylogenetic analysis of the limpets was conducted using 12S, 16S and CO1 mitochondrial genes. Both p-distances and phylogenetic trees suggest that all three morphotypes belong to the same species. Nacella concinna is phylogenetically close to South American species and probably originates from that region, and has spread along subantarctic islands and the Antarctic Peninsula due to currents. The high ecological plasticity of N. concinna to various factors such as wave loads, currents, nutrition, microflora and underwater landscapes may be manifested in the structure of its shell.
For the first time, pure bacteria strains were isolated from the mantle and the digestive system of three N. concinna morphotypes for 16S rRNA barcoding. It was found that the microbiota of N. concinna belongs to marine Proteobacteria (Pseudoalteromonas, Psychrobacter, Shewanella, Halomonas, Cobetia, Psychromonas), Bacteroidetes (Bizionia, Formoza) and Firmicutes (Oceanobacillus). A Maximum Likelihood tree demonstrated that some Pseudoalteromonas strains phylogenetically close to species occurring in the Arctic and Pacific Oceans, which suggests their bipolar distribution.

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Shedding light on the molecular clock of the Antarctic krill Euphausia superba

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Euphausia superba is a high-latitude pelagic organism which plays a central role in the Southern Ocean ecosystem. Krill show daily and seasonal rhythms in physiology and behaviour, which are synchronized with the extremely variable environmental cycles of their habitat. Over the past few years we have focus our efforts to shed light on the molecular architecture and functioning of krill's circadian clock machinery. Our findings describe an ancestral circadian clock, with both mammalian and insect features and a free-running period shorter than 24 hours, involved in the temporal orchestration of gene expression, physiology (energy-storage pathways, oxygen consumption) and behaviour (diel vertical migrations). Moreover, we generated the most comprehensive transcriptome database of krill that allowed us to deeply study gene expression (RNA-Seq and microarray) in adult and larval krill under different natural or simulated photoperiodic conditions. Our results suggest that the photoperiod plays a major role in the entrainment of krill circadian functions when a robust day/night cycle is present. But, when the day/night cycle is strongly biased towards full light or constant darkness, photoperiodic cues might not be sufficient and alternative Zeitgebers might be required. Interestingly, a short free-running period could allow the entrainment of the clock to alternative Zeitgebers characterized by 12 hours periods, such as the morning/evening light transitions or the tidal rhythms. A deeper understanding of the functioning of clock machinery in other polar organisms could reveal whether high-latitude clocks have developed similar strategies to cope with polar environment.

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Benthic Sediment Based Community Compositional Profiling from Underneath the Ross Ice Shelf, Antarctica, as part of the New Zealand Ross Ice Shelf Project (NZRISP)

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Microorganisms in benthic sediments play an important role in regulating the marine ecosystem through complex biogeochemical pathways. The Ross Ice Shelf (RIS) is the largest ice shelf in Antarctica, spanning over 500,000 square kilometers and operating as a prominent physical barrier against sunlight penetration to the underlying water column and benthic sediments below. Current knowledge surrounding how microbial communities within the benthos survive and drive these vital nutrient processes in a carbon limited and sunlight deprived system remain unknown. As part of the NZRISP, this project sought to undertake one of the first studies to examine the composition and structure of benthic microbial communities underneath the RIS. This was achieved using a complex hot-water drilling system to sample sediment cores from the seafloor from two disparate regions of the RIS. Our hypothesis maintains that the different sites will be compositionally distinct from one another as a result of variation in under-ice shelf hydrological processes and nutrient cycling dynamics. Current molecular genetic techniques were used to assess both community composition (DNA-barcoding) and function (Metagenomics). Standard taxonomy database searches revealed that over 40% of the bacterial community were comprised of unknown phyla. Thaumarchaeota were shown to be the top-dominating taxa, an organism typically reflective of an open-ocean system. Species abundance and diversity were strongly correlated with sediment depth, whereby the greatest species richness occurred within the top ~0.5cm. This study aims to be the first of its kind to compare the bacterial communities between two previously unexplored and isolated regions of Antarctica.

1448

Diversity and Ecology of Uncultured Chlorophyta (Viridiplantae) Assemblages in Protected and Non-Protected Sites in Deception Island (Antarctica, South Shetland Islands) Investigated Using an NGS Approach

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Assessment of the diversity of algal assemblages in Antarctica has until now largely relied on traditional culturing approaches. Here we used DNA metabarcoding through high throughput sequencing (HTS) to assess the uncultured algal diversity at two sites on Deception Island, Antarctica. The first was a relatively undisturbed site within an Antarctic Specially Protected Area (ASPA 140) and the second was a site heavily impacted by human visitation, the Whalers Bay historic site. We detected 57 distinct algal taxa, 29 from within ASPA 140 and 50 from Whalers Bay. Of these taxa, 22 were common to both sites, and 35 only occurred at one site. Algal richness was about six times greater than reported in previous studies using culture methods. A high proportion of DNA reads obtained was assigned to the highly invasive species Caulerpa webbiana at Whalers Bay, and the potentially pathogenic genus Desmodesmus was found at both sites. Our data demonstrate that important differences exist between protected and human impacted sites on Deception in terms of algal diversity, richness, and abundance. The western Antarctic Peninsula, including the South Shetland Islands, has experienced considerable effects of climate change in recent decades, while warming through geothermal activity on Deception itself makes this island one of the most vulnerable to colonization of non-native species. The detection of DNA of taxa native to different parts of the world highlights concerns about how the human impacts, both tourism and national operations, and it may influence future biological colonization processes in Antarctica.

1697

Fungal community present in rocks of Ellsworth Mountain, Continental Antarctica

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In the present study, we focused the characterization of the fungal community present in saline crust and the interior of seven different rocks collected in the Heritage Range in the Southern part of the Ellsworth Mountain system, continental Antarctica. Fragments of the saline crust and inner rocks were obtained using mini drill. One (1 g) of each sample was diluted in 0.85% NaCl and 100 µL of a 10-1 inoculated into different culture media (MEA, MEA+17% NaCl, DG18, and DRBC) and incubated at 10 °C for 60 days. A total of 34 fungal isolates were obtained, 23 from the saline crust and 11 from the inner rocks. Fungi were identified using molecular biology methods in taxa of the genera Penicillium, Cladosporium, Naganishia and Filobasidium. Our results indicate that rocks of continental Antarctica shelter a restricted fungal community composed by cold adapted cosmopolitan taxa, which may be adapted to high extreme conditions of continental Antarctica.

932

The whole-genome sequence of the endemic Antarctic fungus Antarctomyces pellizariae reveals an ice-binding protein and provides insights on Leotiomycetes phylogeny.

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Extreme environments, such as the snow-covered surfaces of Antarctica offer the conditions that select the development of life forms with adaptations to extreme conditions. The ability to survive, adapt, and grow at low temperatures may be due to the capabilities to produce antifreeze proteins and ice-binding proteins, which have properties that attenuate the effects of intense cold. In this study, we sequenced and reconstruct the nuclear and mitochondrial genomes of the endemic Antarctic fungus Antarctomyces pellizariae UFMGCB 12416. We identified a putative ice-binding protein-coding gene, determined the protein three-dimensional structure by homology modeling, compared its structure with other publicly available ice-binding proteins that contain the DUF3494 domain, and reconstructed the phylogenetic relationships with others Leotiomycetes from the alignment of thousands of orthologous proteins. Our results will be useful for a better understanding of microbial ice-binding proteins and genomic aspects of psychrophilic fungi.

931

Fungi present on the surface of archaeological materials from different Antarctic sealers sites

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In the current study, we identified fungi present on the surface of different archaeological materials (tissue fragment, skin tissue, wood fragments and whalebone) of the sealers sites from the beginning of the century XIX. Using sterile disposable loops, smears were made on the material in different parts of the pieces, striated on Sabouraud agar and incubated at 10 and 25 °C, according to the storage temperature of the artifacts. We isolated 30 fungi, 19 from the wood fragment, three from the tissue, four from the skin tissue, and four from the whalebone. Penicillium sp. 1 was the most abundant taxa. The genus Talaromyces and Penicilium were recovered from the surface of the wood fragment. In the tissue fragment and skin tissue, species of Trichoderma were predominant, followed by endemic genera Antarctomyces. Penicillium and Mortierella species were isolated from whalebone. The identification of fungi in archaeological artifacts may contribute for the control the biological degradation, one of the most common problems in organics materials, improving consequently the preservation strategies of archaeological collections that constitute the polar heritage.

1112

IcemiRs - Evolution of gene regulation by microRNAs in temperate, Antarctic red-blooded, and Antarctic white-blooded notothenioids

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As Antarctic waters chilled, red-blooded notothenioid ancestors adapted to the cold and subsequently the unique white-blooded icefishes evolved. Gene losses, duplications, and changes in expression patterns are likely sources of adaptation, including to a cold environment and to the transition to the hemoglobin-null phenotype of icefishes. microRNAs (miRNAs), yet underappreciated in Antarctic fish, are endogenous small molecules modulating translation of targeted messenger RNAs. We enquired whether miRNA repertoires and expression patterns evolved during 1) the cold adaptation of Antarctic fish, and 2) the evolutionary remodeling of icefish organs.

To address these questions, we performed high-throughput Illumina smallRNA-sequencing on a panel of organs in three temperate red-blooded notothens, two Antarctic red-blooded notothens, and two white-blooded Antarctic icefishes. We analyzed results using our miRNA data analyzing tool, Prost!, and recently published and as yet unpublished genome assemblies for each species.

Our analysis revealed that the notothenioid miRNA repertoire remained relatively stable over evolution of the group with only a few losses and duplications and the gain of a few novel miRNA genes throughout the phylogeny with no strong association with cold adaptation or icefish evolution. A comparison of miRNA expression patterns between temperate notothenioids, Antarctic notothens and Antarctic icefish organs, however, revealed organ-specificity for many miRNAs and expression level changes between species consistent with a potential role of miRNA regulation in cold adaptation, response to temperature change, and icefish evolution.

1719

The metagenomic and metatranscriptomic responses of coastal phytoplankton assemblages to decreased relative irradiance: an in situ incubation experiment in the Western Antarctic Peninsula

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Antarctic phytoplankton provide vital contributions to carbon cycling and ecosystem trophic interactions in the Southern Ocean via their highly productive seasonal periods. As a result, phytoplankton serve as the basal layer that dictates rates of energy flow and carbon sequestration in Antarctic waters based primarily on their community dynamics. This pivotal role in biochemical processes make the factors influencing key phytoplankton community like composition, production, and nutrient usage crucial to understanding how future phytoplankton assemblages may shift under a fluctuating polar climate. Given already observable shifts in coastal phytoplankton community compositions, abundances, and carbon cycling over the past 20 years, this understanding is even more pertinent in modern times. Explorations into probable abiotic factors have created recent questions on how the effects of light may influence community parameters. This study aims to use meta-omic methods to approach these questions and examine how natural phytoplankton assemblages of the Western Antarctic Peninsula respond to a regime of decreasing ambient irradiance under in situ conditions. To do so, we are utilizing metagenomic, metatranscriptomic, and metalipidomic analyses to gain an in-depth understanding of how the specific diversity, function, and energy content of the communities will change under the experimental conditions. By utilizing a gradient of decreased light to simulate a deepening mixed layer, and using meta-omic tools to quantify dynamic shifts on a high-resolution scale, the results of this study will be significant to predicting changes in coastal phytoplankton community dynamics in the future Antarctic environment.

293

Disentangling the role of microbiomes in subantarctic carbon export South of Australia.

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The Southern Ocean (SO) is the most effective oceanic CO_2 sink globally driven in part by the biological carbon pump. The role played by phytoplankton in carbon export is increasingly well known. However, we lack a mechanistic understanding regarding the microbial community dynamics, ecology and evolutionary patterns especially across understudied biogeographic regions such as the SO. This is crucial for understanding the potential impact of global change on biogeochemical cycling in marine environments and potential feedbacks associated with these processes. We elucidate the role played by microbial communities by analysing samples collected from the subantarctic zone, using a Marine Snow Catcher (MSC) deployed 10 m below the MLD at the Southern Ocean Time Series (SOTS) south of Tasmania. A combination of metagenomics and nutrient analysis was used to clarify microbe mediated carbon export. Preliminary data show increased levels of particulate organic carbon (POC) from suspended to sinking fraction, implying that carbon export occurs within the first 2-hour under gravitational sedimentation. Metagenomic data from these samples are currently being used to generate metagenome assembled genomes (MAGS) following established pipelines. Functional annotation of these MAGS will reveal the repertoire of genes linked to carbon export. Taken together, these findings will provide a clearer understanding of the role of microbial communities on carbon export.

1406

Colobanthus quintesis under CO2 limitation: The response of oxalate oxidase and calcium oxalate crystals.

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The leaves of the Antarctic plant Colobanthus quitensis exhibit a reduced CO2 diffusion, resulting in photosynthetic limitations. Nonetheless, this plant optimizes its carbon assimilation to survive the harsh Antarctic environment; but the mechanism used for C. quitensis to countervail the CO2 diffusion is unclear. We tested whether C. quitensis possess oxalate oxidase enzymes (OxO), whose activity could be associated with the decomposition of calcium oxalate crystals to obtain CO2, maintaining a basal level of photosynthesis, as it has been recently evidenced in other plants and proposed as an “Alarm photosynthesis”. Putative OxO enzymes were identified from the transcriptome by in silico analysis using phylogeny and docking tools. In addition, C. quitensis plants were placed in airtight chambers injected either with ambient air (~400ppm CO2) or soda lime filtered air (~10ppm CO2) for 10 hours. Crystal’s areas in leaves were monitored using polarized-light microscopy and digital image analysis; measurements of electron transport rate (ETR) and OxO activity were also performed for both treatments. A significant reduction in the leaf crystals area was observed in the CO2-limited condition at the end of the experiment. Crystal decomposition was accompanied by increased OxO activity and a slight decrease in the ETR. Our results suggested that a CO2 limiting condition is directly related with CaOx crystals decomposition. Consequently, the CaOx crystal decomposition might play a role as a complementary endogenous mechanism facilitating the CO2 supply in the Antarctic plant C. quitensis to compensate the reduced CO2 diffusion of leaves developed under its natural habitat.

1097

Do Antarctic giant isopod juveniles have the molecular repertoire to cope with Southern Ocean warming?

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The effects of warming in early life stages of Antarctic marine invertebrates have rarely studied. Some studies evaluating the upper thermal limits of early juveniles compared to adults, suggest that juveniles are more resistant than adults; however, the molecular basis of this resistance has not yet been elucidated. Juveniles of the isopod Glyptonotus antarcticus were extracted from the marsupium to conduct differential gene expression analysis. Using a RNA-Seq approach, the response to thermal stress was evaluated by using pools of five isopods that were exposed to 5 ° C for 24 hours evaluating the response at 1, 6, 12 and 24 hours. Two control groups (1 and 24 h) were maintained at 1 ° C. In total, 18 separate RNAseq libraries from each temperature treatment were generated using the Illumina HiSeq2000 platform. Differentially expressed genes (between control and heat stress animals) were functionally enriched with processes relating to cellular stress, antioxidants and ubiquitination pathways. The classical chaperone response was not induced and some small Hsps were up-regulated. The cathepsin L and cuticule proteins related to molting and development were down–regulated genes. These results show that the transcriptomic response of G. antarticus juveniles changes over time during thermal stress, however, they may not have the physiological plasticity necessary to deal with a further warming scenarios expected for future decades.

1441

Genomics and Genome Mining of Extremophile Lichens in Antarctica

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Lichens represent some of the oldest and most diverse symbioses on Earth. Lichens consist of a photobiont (cyanobacterium/alga), a mycobiont (fungus), which together form a unique structure called the thallus in a symbiosis with multiple microorganisms. Lichens play a vital role in ecosystems as they are essential in soil formation, naked soil colonization, and nutrient uptake and release for plants. Lichens can colonize a wide range of substrates, from natural surfaces to man-made materials. They can also tolerate extreme environmental conditions and even resist outer space conditions.

Lichens in Antarctica are able to adapt to the cold and dry conditions through robust resistance to frost and photosynthetic capabilities. However, no study has attended to identify potential genes that might confer the capacity to survive such harsh conditions, and the functional roles of these genes in the symbiosis.

Here we analyzed varied species of lichens collected across locations in the South Shetland Islands and Graham Land in February 2020. We analyzed the lichens microbiome, identified extremophile microbes, and annotated genes that might be related to extreme conditions. Additionally, we found multiple unknown biosynthetic gene clusters (BGCs) that are related to the production of antimicrobials, indicating that lichens from Antarctica could be a source of new antimicrobials. Altogether, these results not only expand our knowledge of Antarctic's biodiversity and serve as a baseline for further multi-omics studies in lichens, but also evidence the potential of lichens in bioprospection and exobiology.

1498

A comparative metagenomic analyses of the microflora present in both wild and captive colonies of Gentoo and Chinstrap penguins

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Penguin colonies in Antarctica leave their stamp on the land in the form of large guano deposits.The microbiota found within this largesse can tell us quite a bit about the nutritional and physiological well being of these penguin populations--both those found on around the Antarctic peninsula as well as their relatives in captivity--as this microbial flora is plays a significant role in metabolism, synthesis, and secretion of vital nutrients that sustain their host.

In February 2020, multiple samples of guano were collected from colonies of Gentoo (Pygoscelis papua ellsworthy) and Chinstrap penguins (Pygoscelis antarcticus) along Graham Land and the South Shetland Islands. Then, guano samples were likewise collected from colonies cared for in captivity at Central Park Zoo in New York City.

Our metagenomic analysis comparing the gut microbial flora present in those colonies that inhabit the Antarctic peninsula to those in captivity offers insight into the influence of containment and diet upon gut microbial population. This study is intended as a pilot toward an expanded, longitudinal investigation of additional colonies and species in the wild and in captivity.

1586

Transcriptome analysis of hormone related genes induced by temperature changes in the Antarctic marbled rockcod Notothenia rossii

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Antarctic marbled rockcod Notothenia rossii belong to Antarctic notothenioid which is the most dominant fish fauna in the Southern Ocean. Antarctic notothenioid teleost have evolved to adapt to thermal stable and cold Antarctic Ocean. In this study, we examined differentially expressed hormone related genes regulated by temperature changes using RNA sequencing method. We investigated transcriptional differences of three different organs (liver, blood and brain) at heat shock stress (from 0°C to 4°C). We found that 19 steroid related genes and 31 hormone related genes were differentially expressed in brain and nine steroid related genes and 12 hormone related genes were differentially expressed in blood. Further in-depth study are need to correlate genetic information between hormonal metabolites and receptors according to temperature conditions and determine hormone types and receptor based metabolic functions by hormone profiling.

1608

Multiple application potential of Antarctic Micractinium KSF0031

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Antarctic microalgae have several advantages. Their evolutionary adaptation to a wide range of habitats and extreme environments has allowed them to have an abundance of biological and genetic diversity, as well as to produce a variety of bioactive molecule. We have been conducting research to apply Antarctic microalgae from basic to applied research for multiple purposes.
We here introduce Antarctic freshwater microalga KSF0031, one of new species of the genus Micractinium collected on the snow surface on the South Shetland Islands, Antarctica. Based on the morphological and molecular characteristics, it was named Micractinium variabile sp. Nov. KSF0031 (hereafter referred to as KSF0031). We analyzed the transcriptome of KSF0031 and used nanopore sequencing to produce 4,617,230,585 bp and an average read length 4,957bp. The contig number was 103 and N50 contig size is 1.9Mbase. We are especially analyzing unsaturated fatty acid-related genes and gene coding low-temperature active enzyme proteins. Also, we are investigating the chemical composition and the biological function to reveal the antioxidant, anti-inflammatory, and anticancer potentials of Antarctic microalga KSF0031.

1528

Comparative analysis of key genomic features identified in Antarctic blackfin icefish to the genome of the Antarctic bullhead notothen

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Antarctic fish (Notothenioidei) have adapted and evolved with developing cold-adapted genomic signatures, phenotypes, and physiology to survive in the earth's coldest marine environment. Notothenioideis are recognized in two types based on different physiological features, including the presence or absence of hemoglobin in their bloods. Antarctic bullhead notothen, Notothenia coriiceps comprises red-blooded fish (having hemoglobin, myoglobin and red blood cells in the blood) and has been used as a good model to understand the adaptation to the Southern Ocean due to high biomass and a wide range of distribution in Antarctica. Icefish such as Antarctic blackfin icefish, Chaenocephalus aceratus have colorless blood due to lack of hemoglobin and myoglobin gene clusters in the genome with the absence of red blood cells in the blood. To compensate for the lack of oxygen carrier protein, icefish have evolved to possess a large volume of blood, scaleless skin, enlarged head, and enhanced vascular system. Since the genome information of N. coriiceps and C. aceratus is available, comparative genomics and bioinformatics enable us to figure out how the key molecular pathways are different between Antarctic fish as well as in comparison with temperate fish. In this study, we compared two Antarctic fish genomes (N. coriiceps and C. aceratus) to discover commonly developed genomic features and unique characteristics. This result can be helpful to understand unique evolutionary trajectory of each Antarctic fish.

1469

Identification of AP2 transcription factors responsible for the cold tolerance of the dominant Antarctic moss Sanionia uncinata, based on de novo genome assembly and genetic transformation approach

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Mosses in Antarctica grow mostly in coastal areas and are expected to have developed various unique physiological/molecular mechanisms to survive in extreme environments. Sanionia uncinata (Hedw.) Loeske is a dominant moss species in the maritime Antarctic and considered as a good target to investigate genes associated with abiotic stress tolerance of mosses. Here, we aimed to select and characterize function of a key transcription factor which induces the cold tolerance process in S. uncinata at the molecular level. At first, we report the draft genome sequence of an Antarctic S. uncinata, obtained using third-generation PacBio sequencing technology. About 1 million reads were attained from four Sequel sequencing runs and merged together into a single dataset of 21 Gb. The de novo assembly produced 673 contigs comprised of 621 Mb with an N50 contig length of 2.2 Mb and the longest contig length of 10.3 Mb, and a total of 28,651 coding genes were inferred. Based on the transcriptome analysis, we could find twenty genes containing AP2 DNA binding domain, showing transcriptional induction in response to cold stress treatment (2℃). Then to characterize their functions related to cold tolerance, we generated transgenic plants which constitutively express SuAPL genes using the model moss Physcomitrella patens, exhibiting significantly lower cold tolerance than the Antarctic moss. Some of transgenic mosses displayed enhanced freezing tolerance in terms of electrolyte leakage under freezing conditions, compared to wild-type. These results suggest that SuAPL have important functions in cold adaption of S. uncinata to extreme Antarctic environments.

1607

The seasonal transcriptome dynamics of Antarctic moss, Sanionia uncinata (Hedw.) Loeske, throughout the year in natural environments, reveals the molecular adaptation of extremophile plants

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Maritime Antarctic is covered with snow and ice for most of the year, but during the austral summer season, snow melts and a variety of vegetation is revealed. During this short growing season, terrestrial plants actively perform cellular activities under the prolonged daytimes. But even in this short summer, the sub-zero temperatures, dryness, continuous strong light, and UV radiation are very extreme conditions for plant growth. And after these summers are over, the snow starts to pile up and the plants stop growing and enter the dormancy state in a long and dark winter. Here, in this study, we investigated the annual transcriptome response of extremophile plants in a natural environment. During the 2015-2016 winter/summer station study, we had sampled Sanionia uncinata, one of the dominant bryophyte species of the maritime Antarctic, naturally habituated in the King George Island (62°14′ S; 58°44′ W), on a monthly basis, and conducted transcriptome analysis. As a result, we could identify groups of genes that fluctuate with rhythmicity according to the seasonal changes. The weighted co-expressed gene network analysis enabled to construct a correlation network on climate-gene expression and to identify the groups of genes responding to changing climatic factors in a natural environment.

1037

Mitochondrial diversity and physico-chemical environment modulate gene expression in the Southern Ocean bivalve Aequiyoldia eightsii species complex

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Regulation of gene expression is a pivotal adaptive mechanism of organism facing environmental variation. This regulatory capacity is constrained, however, by attributes inherent to organisms (genotypes). In this study, we analysed gene expression patterns and Single Nucleotide Polymorphisms (SNPs) across South American and Antarctic populations of Aequiyoldia shallow marine bivalves. We explored gene expression patterns in response to 1) natural environmental conditions on continental and local scales (1000 km vs 1 km) as well as 2) nuclear and mitochondrial genotypes. We validated our results by contrasting the observed magnitudes of differential expressed genes (DEGs) with magnitudes expected by chance in randomized group comparisons. Trans-Drake comparison resulted in highly distinct nuclear and mitochondrial SNP compositions coupled with striking differences in DEGs. Mitochondrial SNPs divided Antarctic animals into two groups, each composed by organisms featuring mitochondrial homoplasmy and heteroplasmy (in total: four mitotypes). Mytotype pattern was not reflected in nuclear SNPs. Habitat comparison (animals from rocky, sandy, muddy grounds) revealed clear differences in DEGs at local scale in Potter Cove, without significant nuclear or mitochondrial genetic structure between stations. Interestingly, differential expression analysis between mitotypes resulted in a number of DEGs in the same order of magnitude as driven by the environment, distinguishing heteroplasmic from homoplasmic organisms at a level well above the number of DEGs expected by chance. Field-based transcriptomics provide an unprecedented understanding of the mechanics of local adaptation and will prove especially valuable in times of rapid climate change.

1447

Functional resilience of nitrogen fixation over a salinity gradient on the McMurdo Ice shelf

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The ability of ecosystems to accommodate to environmental change is dependent on the ability of keystone taxa and communities to respond to perturbations through resistance or resilience mechanisms. Functional resilience describes sustained critical ecological processes through shifts in composition or physiological flexibility in the face of environmental change, critical to ecosystem integrity. In Antarctic terrestrial aquatic environments, cyanobacteria dominated microbial mats are fundamental components providing biomass, productivity and critical biogenic habitat. In many locations this includes driving nitrogen dynamics through nitrogen fixation. In this study we analyse the ability of microbial mats to sustain nitrogen fixation capacity across a range of environmental conditions. The work was carried out on the McMurdo Ice Shelf in ponds with diverse chemical compositions, the 5 selected ponds spanned a range of conductivities from 400 to 28,400 µS/cm, all with biomass dominated by microbial mats. In these ponds there is evidence to show ponds can rapidly shift to more saline or fresh with changing hydrologic balance. In each pond mat nitrogen fixation was measured using the acetylene reduction assay, and mat community composition characterised using 16s rRNA gene sequencing and microscopy. Nitrogen fixation was sustained at comparable rates over the entire salinity range, while the dominant nitrogen fixing cyanobacteria transitioned from Nostocales to Nodulariales as salinity increased. We conclude that, in respect of nitrogen fixation, microbial mats in Antarctic ponds show functional resilience to changes in pond salinity through turnover of dominant diazotrophs.

1400

Molecular insights into phytoplankton assemblages along natural iron gradients at the West Antarctic Peninsula

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The West Antarctic Peninsula (WAP) is a highly productive coastal environment where phytoplankton, mainly diatoms, form the base of a rich, polar marine food web. However, the WAP has experienced significant warming over the last 50 years and may serve as a sentinel for climate change in Antarctica. Long-term studies of phytoplankton community diversity, using high-performance liquid chromatography or the 18S rDNA gene marker, have suggested transient limitation by the micronutrient iron (Fe); however, the impact of climate change on phytoplankton molecular ecophysiology, using gene expression, remains underexplored. To better understand whether diatoms, and other phytoplankton functional groups differ in their gene expression responses to changes in Fe availability, a comparative analysis of phytoplankton assemblages from inshore and offshore regions of the WAP were performed using metatranscriptomic approaches. By using next-generation sequencing technology, we obtained thousands of differentially expressed genes representing the full complement of iron metabolism and transport, as well as photosynthesis, iron homeostasis, and N assimilation. Additionally, specific gene expression patterns (e.g. iron starvation induced proteins and genes encoding iron-free proteins) corresponded to diatom iron physiological status, thus representing potential molecular indicators for iron limitation. This research provides new insights on the mechanisms that may underpin physiological responses of ecologically relevant WAP phytoplankton species to variations in iron availability and their potential effects on ecosystem processes and carbon export.

1687

Fungi present in lacustrine sediments of Antarctic Peninsula

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In lacustrine ecosystems of Antarctica fungi play a fundamental role in decomposition of organic matter suspended in water. Considering that little is known about the diversity and ecological roles of fungi in these habitats, we evaluated 8 different lakes of Peninsula Antarctica. A total of 195 fungal isolates were recovered, and among them 42 taxa were classified in phyla Ascomycota, Basidiomycota, and Mortierellomycota. The fungal assemblages were rich and diverse, composed principally of cold cosmopolitan and psychrophilic endemic taxa recognized as decomposers, symbiotics and pathogens. Some of the identified species such as Thelebolus globosus, Antarctomyces psychrotrophicus, Pseudogymnoascus verrucosus, Vishniacozyma victoriae, and Phenoliferia sp. were frequently in our sediment samples. Other potential new species were also detected in this work. In addition, we detected fungal taxa and isolates able to produce bioactive compounds that may represent the source of prototype molecules for applications in medicine and agriculture. The dynamics and balance of this fungal community represents an interesting aquatic web model for further ecological, evolutionary and biotechnological studies under extreme conditions and potential climate changes in these regions.

Assessment of uncultured fungal diversity in lake sediments of Vega Island, Antarctica

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Vega Island has many lakes and ponds which are a potential archive for studies of climate and environmental changes in Antarctica. Historically, Vega also hosts many species of lichens, plants, animals and associated microbiota. In addition, the island is considered an important place for paleontology studies. In this pioneering study we evaluate fungal diversity in lake sediments, using DNA metabarcoding through high throughput sequencing (HTS), never mentioned in the literature for Vega Island. A sample of Copepodo and Pan Negro lakes were collected using pvc pipes, and 500 mg of sediment, from the central portion of the core, were used for DNA extraction. The previous taxonomic annotation showed OTUs associated with the phyla Ascomycota, Basidiomycota, Mortierellomycota and the zoosporic fungi Rozellomycota. A total of 111 taxa were found and clustered in 11 classes, 26 orders, 44 families, 69 genera, and 67 species, and among them 32 species were shared between the two lakes, and some of them were not yet described for lake environments from Antarctica. The most abundant taxa were Pseudogymnoascus appendiculatus, Leotiomycetes sp. and Pseudogymnoascus roseus, and 44 taxa did not correspond with species deposited on UNITE database and can represent species that still unknown to the Antarctic environment.

1683

Identification of fungi present in a lake environment on King George Island, Antarctica

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In order to know the microbial portion present in the Antarctic lakes, the present study aimed to assess the diversity of the fungal community present in string baits suspended in a lake in Punta Hennequin, King George Island, Antarctica. Polystyrene bags containing three fragments of sterilized cotton string were launched and fixed at two points on the lake, where they remained for two years. The string fragments were processed in duplicates using Dichloran agar, minimal medium, Marine agar, and malt extract agar. Forty-eight filamentous fungi and 49 yeasts were obtained. Among these, 83 were identified as belonging to the genera Thelebolus, Dactylaria, Goffeauzyma, Phenoliferia, Vishniacozyma, Chalara, Pseudogymnoascus, Mortierella, Mrakia, and Leucosporidium. Our results indicate that the Antarctic lakes represent habitats for endemic and cosmopolitan fungi, which can present several physiological adaptations under extreme conditions, which may be useful to use in biotechnological processes.

1680

Uncultured fungal diversity in Antarctic marine sediments

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In the present study, we evaluate the uncultivable fungal diversity of marine sediments of Maxwell Bay, South Shetlands, Antarctica using DNA metabarcoding through high throughput sequencing (HTS). Marine sediments of 150 m and 250 m depth were sampled using a gravity corer. Aliquots of 15 g of sediment were suspended in 0.9% saline and the supernatant filtered in 0.44 µm membrane, which was used for the DNA extraction. The taxonomic annotation showed OTUs associated with the phyla Ascomycota, Basidiomycota, Mortierellomycota, and Mucoromycota. OTUs of 107 different taxa were detected and clustered in 14 classes, 29 orders, 44 families, 56 genera, and 54 species. Some of these species such as Malassezia globosa, Malassezia restricta, Mortierella alpine, Mortierella fimbricystis, Mortierella gamsii, Phaeosphaeria dennisiana, Pseudogymnoascus roseus and Rhodotorula mucilaginosa occurred in the sediments of 150 and 250 m depth. Leotiomycetes sp., Pseudogymnoascus roseus and Diaporthales sp. were the most abundant taxa (15734, 11330, 3721 reads respectively). In addition, 53 OTUs did not correspond with any species deposited on database and may represent fungi propagules that still unknown to the Antarctic environment.

1682

Uncultured fungal diversity in permafrost of the Antarctic Peninsula

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The aim of the present work was to access the fungal permafrost community of the Deception and King George islands, Antarctica using the DNA metabarcoding through high throughput sequencing (HTS). Twenty-three operational taxonomic units (OTUs) were detected. In the permafrost of Deception Island, Aspergillus restrictus, Scheffersomyces amazonenses, Rhodotorula mucilaginosa, Mortierella sp. 1, and Mortierella sp. 2 were detected. In permafrost of King George Island, Aspergillus westerdijkiae, Penicillium brasilianum, Penicillium chrysogenum, Pseudogymnoascus sp., Candida sp., Leucosporidium creatinivorum, Rhodotorula mucilaginosa, Mortierella sp. 1, and Mortierella sp. 2 were found. Some taxa detected represent the first records in Antarctic permafrost. Fifteen OTUs represented unclassified taxa might represent new species. The diversity, richness, and abundance between the permafrost of the two islands were significant and further studies are necessary increase the knowledge of the real fungal community in Antarctic permafrost.

1684

Identification of fungi present in biofilm of Kroner Lake, Deception Island, Antarctica

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In the Antarctic environment, lakes represent untapped habitats that can be used to study microbial diversity and ecology in extreme conditions. The present study evaluated the diversity of the fungal community present in biofilm sampled at Kroner Lake, Deception Island, Antarctica. The biofilm was collected in 15 points of the lake and the samples processed in the culture media Sabouraud dextrose agar, Marine agar, and incubated at 10º C. Forty-four filamentous fungi and 22 yeasts were obtained. Of these, 50 were identified as belonging to the genera Metschnikowia, Antarctomyces, Pseudogymnoascus, Mortierella, Tricellula, Leucosporidium, Holtermanniella, Vishniacozyma, Arthroderma, Rhodotorula, and Debaryomyces. The species found in the biofilm include endemic or cosmopolitan taxa and may be responsible for the primary decomposition process of organic materials.

704

Sex determination mechanisms in Antarctic Notothenioid fish

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Antarctic notothenioid fishes provide an iconic example of a marine species flock. What evolutionary mechanisms propelled this spectacular burst of biodiversity? Reproductive isolating mechanisms can include the origin of new sex determination genes and new sex chromosomes. To uncover sex-linked loci in notothenioids, we used RAD-seq and pool-seq to identify sex-specific genetic polymorphisms in populations of males vs. females in several notothenioid species and mapped reads along genome sequences. For blackfin icefish (Chaenocephalus aceratus), results identified a polymorphism on ancestral notothenioid chromosome-9 (chrAN9) that was fully linked to phenotypic sex. This sex-linked locus resides between tandem duplicates of bmpr1ba (called bmpr1ba.1 and bmpr1ba.2), which, along with bmpr1bb, represents a teleost duplicate of human BMPR1B. The mammalian Bmpr1b protein is part of the Amh receptor dimer, the other part of which (Amhr2) is the major sex determination gene in several fish species. A male-specific single nucleotide polymorphism in bmpr1ba.2 is predicted to strongly alter protein function, likely acting as a dominant, Y-chromosome-linked, constitutive activator of testis development. For South Georgia icefish (Pseudochaenichthys georgianus), we found a sex-linked locus on chrAN12 that contains a tandem duplication of three genes, including gsdf (gonadal soma derived factor), variants of which are the major Y-chromosome sex determination gene in several fish species. All icefishes examined have tandem duplicates of both bmpr1ba and gsdf, suggesting that different lineages appropriated different pre-existing tandem duplications to become sex determination genes. This finding is predicted if new sex determination genes helped promote lineage diversification in the Antarctic notothenioid radiation.

1219

Comparative genomics in the search for adaptations to life on low temperatures in the Metschnikowia genus

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The Metschnikowia genus comprises ascomycetous yeats from diverse environments. Besides the flower associated species there are also aquatic species, macroalgae associated and micro crustaceans' parasites. M. bicuspidata, the most widespread, is found on almost every ocean and many temperate lakes. Despite being freeze tolerant, M. bicuspidata is not present in Antarctic Ocean. M. australis, a closely related species, occupies its niche on these southern waters. Also freeze tolerant, M. australis performs better at low temperatures, as we show in this study. We have sequenced M. australis genome and investigated it together with M. bicuspidata and other 33 publicly available Metschnikowia genomes searching for freeze tolerance associated elements. All genomes were predicted and annotated using the same pipeline, and 1317 common single copy orthologous genes were used to reconstruct these yeasts phylogeny. We observed that M. australis has a smaller genome, with less predicted coding sequences and repetitive content in comparison to M. bicuspidata. We have also developed a homology-based network approach to visualize and identify orthologous genes shared among genomes, which shows paralogous expansions shared by M. australis and M. bicuspidata genomes and also exclusive to each organism, which may relate to adaptions do cold environments. 249 M. australis exclusive CDSs were analyzed by 3 Antifreeze protein classifiers to select the 17 most prominent candidates for in vivo detection. We found that 14 of those are expressed at 4˚C. Most have no similarity to any know gene, and future analyses will be done to identify their influence in freeze tolerance.

1209

Uncultured cryptic fungal diversity in soils of Deception Island, Antarctica: taxonomy and distribution in protected and non-protected areas using an NGS approach

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We assessed the soil micro-fungal diversity in soils from two sites on Deception Island, Antarctica using DNA metabarcoding through high throughput sequencing (HTS). The first site was within an Antarctic Specially Protected Area (ASPA 140), representing an undisturbed area, and the second was at Whalers Bay, a historic site that is popular with visitors. We detected 346 fungal OTUs dominated by the phyla Ascomycota Basidiomycota, Mortierellomycota, and Mucoromycota. We also detected taxa of the rare phyla Chytridiomycota and Rozellomycota, which occurred with moderate frequency in both areas and are often difficult to detect using traditional isolation methods. A total of 127 OTUs were detected in the ASPA, 142 from Whalers Bay, and 113 were common to both areas. The fungal assemblages at both sites displayed high diversity, richness, and dominance indices. Sixty-five OTUs were considered dominant (those with >1,000 reads), with Cladosporium sp., Pseudogymnoascus roseus, Leotiomycetes sp. 2, Penicillium sp., Mortierella sp. 1, and Mortierella sp. 2 achieving >45,000 reads). Additionally, 23 OTUs were identified only at higher taxonomic levels (phylum, class, order, and family) and may represent new taxa and/or new records to Antarctica. Our data indicated that the soil micro-fungal diversity in the protected area was similar to that in the highly visited area. The overall diversity detected included a combination of apparently endemic and cosmopolitan taxa.

1220

Cultured fungal diversity in permafrost of Antarctic Peninsula

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We accessed the diversity and distribution of the cultivable fungi present in permafrost and active layer obtained from Robert, Livingston, and Deception islands, Antarctica. Using different culture media, 58 fungal taxa were identified, which 27 from permafrost and 31 from the active layer; however, only 5 occurred in both microhabitat. Mortierella and Pseudogymnoascus were the most and abundant taxa. The fungal diversity found in the different sites was moderate to high. Forty taxa could not be identified in species level and may represent new species. Our results demonstrate that permafrost shelter viable fungal species with moderate to rich diversity assemblages across the Antarctic Peninsula. The Antarctica Peninsula represents the major area on earth under effects of the global warm climate changes, and permafrost represents a concern with the release of trapped gases and microorganisms. Along with the physico-chemical analysis, the results obtained in this study suggest that the geological and biological history of these soils is the factor responsible for shaping the fungal community in these environments.

819

Southern Ocean Acidification impacts: calcifying vs non-calcifying species

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Southern Ocean organisms are thought to be particularly vulnerable to ocean acidification (OA), as they inhabit cold waters where calcite-aragonite saturation states are naturally low. It is also generally assumed that calcifying animals would be more affected by the OA. In this context, we proposed to study the impacts of low-pH on two dominant species from an Antarctic fjord, one non calcifying, the ascidia Cnemidocarpa verrucosa and the bivalve Yoldia eightsii. We report results of ~2 months of experiment, comparing the molecular mechanisms underlying responses under two pCO2 treatments (ambient and low-pH). Enzymatic activity (spectrophotometry) and RNAseq using mass sequencing techniques were performed. Significant effects were found in caspase (Mann-Whitney; W=26.00; $p=0.02$) in C. verrucosa at 2 months in low-pH condition. There was an increase in the regulation of 224 genes and a decrease in the expression of 111 (FC≥2; p-value≤0.05). Particularly, low-pH caused an up-regulation of genes involved in the immune system and antioxidant response. While in the infaunal bivalve Y. eightsii less differentially expressed genes were observed, an up-regulation of 34 genes and a decrease in the expression of 69 genes were found (F ≥2; p-value≤0.05). This work addresses the effect of OA in two abundant species from Potter Cove and surprisingly showed a more pronounced response in the non-calcifying species. The present approach is being carried out in other species, such as corals, limpets and snails, which in turn will allow us to increase the understanding of the response capacity of Antarctic coastal ecosystems to climate change.

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Diversity of total and cultivable siderophore producing marine bacteria: influence on phytoplankton growth in the Indian sector of Southern Ocean

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Indian sector of Southern Ocean (ISO) is a climate-sensitive region for global biogeochemical cycles and ocean warming in response to climate change. Microbes are key drivers of important biogeochemical processes. Yet, diversity and abundance of microorganisms and their interactions with phytoplankton population remain poorly studied in ISO, particularly with regards to diversity of total bacterial forms and cultivable forms of siderophore producing bacterial population. Here, we present first set of amplicon sequencing of 16S rDNA to identify total bacterial population diversity. We also present the cultivable siderophore producing bacterial diversity from ISO. Gammaproteobacteria was found to be dominant group in various fronts of ISO, while light harvesting alphaproteobacteria dominated in polar stations. Bacterioidetes, Cyanobacteria and Deferribacteres were dominant bacterial phyla other than Proteobacteria. The cultivable bacterial population was predominantly derived from Gamaproteobacteria, Actinobacter and Bacilli and tested positive for siderophore production. Selected siderophore producing bacterial isolates were grown along with two most abundant phytoplankton Gephyrocapsa oceanica, a cocclolith and diatom (Skeletonema costatum) from different oceanic environments to test the effect of siderophores and iron on plankton growth and plankton bacterial interaction. Results clearly indicate that growth of Gephyrocapsa oceanica was always stimulated in presence of bacteria with or without iron and siderophores. In case of the diatom, presence of bacteria suppressed the growth of the diatom. Our experiment shows that bacterial-phytoplankton interactions are species specific and same bacterial species elicit variable response to different phytoplankton species. Such species-specific responses can have wider implications in Southern Ocean biogeochemistry.

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Integration of comparative and functional genomics as a tool for linking phylogeny to function in cold temperature environments

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Traditionally microbial surveys have been based off from 16S rRNA genes which have been used to infer the phylogenetic identity and functional potential of organisms. While these surveys are easily completed it is not resolved whether organisms with similar 16S rRNA sequences behave similarly in the environment. In contrast to 16S rRNA surveys genomics facilitates the study of the genetic information of an individual organism. To understand how the selective pressures of the Antarctic influence genetic adaptations we investigated the genomic traits of a Janthinobacterium spp. in comparison to genomes of 35 published Janthinobacterium species. We hypothesized that genome shrinkage and specialization to narrow ecological niches would be energetically favorable for dwelling in an ephemeral Antarctic stream, however, the genome of Janthinobacterium sp. CG23_2 was on average 1.7 ± 0.6 Mb larger and predicted 1411 ± 499 more coding sequences compared to the other Janthinobacterium spp. Putatively identified horizontal gene transfer events contributed 0.92 Mb to the genome size expansion of Janthinobacterium sp. CG23_2. We aimed to determine whether genome size was correlated to increased functional capacity. Our data suggest that genome plasticity and the abundant complementary genes for sensing and responding to the extracellular environment supported the adaptation of Janthinobacterium sp. CG23_2 to this extreme environment. Additionally, to understand the functional role of individual organisms in Antarctic environments we have recently been focused on developing strategies to analyze active fractions of microbial assemblages in order to determine the ecological function of individual organisms.

1420

Evolution of the immune system in two Antarctic Notothenioids

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Fish rely significantly on innate immune response, extremely important for survival in aquatic environments, rich in bacteria, parasites, fungi and viruses. Antarctic notothenioid fish evolved from 25 Myears ago in a very cold and stable environment through adaptive radiation, likely developing specific immune responses and host-parasite interactions. Little is known about the functioning and adaptability of their immune system, an issue as climate change can lead to occurrence of novel pathogens or disruption of microbial balance in Antarctic Ocean.
Experiments with Notothenia coriiceps and N. rossii were performed in Great Wall Station, King George Island, in Antarctic summers of 2017 and 2019. The experimental design included groups kept at 2ºC and 6 ºC (n=6/8), treated with LPS or Poly:IC in different exposure time/routes. Plasma and tissues involved in the immune process were collected, and functional assays performed. Lysozyme and antitrypsin show differential responses to LPS and Poly:IC at both temperatures. Transcriptomic analysis in headkidney showed that gene networks related to WBC production are active in LPS-challenged fish and genes related to innate response are differentially expressed in all interface tissues. Skin and gut microbiomes revealed tissue specific diversity and different community responses to these challenges, with skin showing higher variability. Comparative in silico analysis of TLRs gene family showed that several genes evolved under positive pressure of the extreme conditions and novel TLR genes were characterised.
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Sex identification from distinctive gene expression patterns in Antarctic krill (Euphausia superba)

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Antarctic krill (Euphausia superba) is a highly abundant keystone species of the Southern Ocean ecosystem, directly connecting primary producers to high-trophic level predators. Sex ratios of krill vary remarkably between swarms and this phenomenon is poorly understood, as identification of krill sex relies on external morphological differences that appear late during development. Sex determination mechanisms in krill are unknown, but could include genetic, environmental or parasitic mechanisms. Similarly, virtually nothing is known about molecular sex differentiation. The krill genome has to date not been sequenced, and due to its enormous size and large amount of repetitive elements, it is currently not feasible to develop sex-specific DNA markers. To produce a reliable molecular marker for sex in krill and to investigate molecular sex differentiation we therefore focused on identifying sex-specific transcriptomic differences. Through transcriptomic analysis, we found large gene expression differences between testes and ovaries and identified three genes exclusively expressed in female whole krill from early juvenile stages onwards. The sex-specific expression of these three genes persisted through sexual regression, although our regressed samples originated from a krill aquarium and may differ from wild-regressed krill. Two slightly male-biased genes did not display sufficient expression differences to clearly differentiate sexes. Based on the expression of the three female-specific genes we developed a molecular test that for the first time allows the unambiguous sex determination of krill samples lacking external sex-specific features from juvenile stages onwards, including the sexually regressed krill we examined.

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Gene expression pattern analysis provides insights into the cold-adaptation mechanisms of an Antarctic yeast, Glaciozyma antarctica PI12

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Psychrophilic yeast, Glaciozyma antarctica PI12 from the sea ice in the Southern Ocean has adapted well to grow and survive at low temperatures. However, the information on its adaptation strategies and mechanisms at the molecular level is limited. Hence this project was carried out to sequence and analyze the whole transcriptome to understand the cold-adaptation strategies of G. antarctica PI12. G. antarctica PI12 cells, grown in YPD medium at its optimal growth temperature of 12°C were exposed to freeze stress at 0 and -12°C for 6 h and 24 h. A hundred and sixty-eight genes were differentially expressed and the gene expression patterns were dependent on the severity of the cold. More genes differentially expressed at -12°C when compared to 0°C. G. antarctica PI12 was found to share some common adaptation strategies with other yeasts, namely, Saccharomyces cerevisiae, and Mrakia spp. At the same time, it has some unique strategies and mechanisms too. Among the strategies were the production of anti-freeze protein to prevent ice-crystallization inside and outside the cell. Additionally, several molecular chaperones, detoxifier of reactive oxygen species (ROS), and transcription and translation genes were constitutively expressed in G. antarctica PI12 to ensure the cells were always prepared to endure the fluctuating freezing temperatures. Unexpectedly, G. antarctica PI12 was found to use nitrite as an alternative terminal acceptor of electrons when the oxygen level was low. These mechanisms coupled with several other common mechanisms ensured G. antarctica PI12 adapted well to the cold temperatures.

SCAR 2020

Antarctic Science - Global Connections

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SESSION 20

THE EFFECTS OF CHANGE ON SOUTHERN OCEAN ECOSYSTEMS: UNDERSTANDING, MODELLING, PROJECTING, AND MANAGING CHANGE IN SOUTHERN OCEAN SPECIES AND FOOD WEBS

Nadine Johnston
Rachel Cavanagh, Andrew Constable, Jess Melbourne-Thomas, Monica Muelbert, Eugene Murphy, Madeleine Brasier

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

1449

The state of Adélie penguin colonies in the Ross Sea Region

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Adélie penguin (Pygoscelis adeliae) colonies have been monitored by Antarctica New Zealand in the Ross Sea region since the early 1980s. This region contains around a third of all Adélie penguins in Antarctica and includes their most southerly recorded range. Annual census data are available for many key colonies making for a remarkably robust dataset. Adélie penguins are considered an indicator species due to their sensitivity to climate factors and role within the Antarctic food web. They subsist on a diet of krill and Antarctic silverfish making them primary trophic competitors with emperor penguins, Antarctic toothfish, and various whale species alike.

The harsh reality of life in the Antarctic creates an ecosystem uniquely vulnerable to change. 30 years of Adélie census data are explored to determine the role of environmental covariates as population drivers in the Ross Sea. Changepoint analysis reveals the clear increase in population growth of 5 Ross Island colonies, reinforcing the close link between Adélies and sea-ice conditions. The results highlight that trophic cascades can impose complex and far-reaching consequences on an ecosystem by disrupting the careful balance between Adélie penguins, their trophic competitors, and shared prey. In light of a rapidly changing climate and increasing human presence in Antarctica, continued monitoring of Adélie colonies is necessary in order to fulfil CCAMLR's ecosystem-facing approach to management. Historical observation techniques can be bolstered with novel and exciting remote-sensing technology, building and improving our understanding of ecology in the Ross Sea and wider Antarctic environment.

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Biomarkers of Antarctic sediments from King George Island as indicators of sources and processes related to oceanographic conditions

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The abundance and biomass of the trophic web in Antarctic marine systems are influenced by the supply of organic matter that promote the plankton and, consequently, the other trophic levels. Although scientific knowledge identifying intense environmental changes, the fragility of this ecosystem is still little perceived. One of the ways to understand the complexity of this environment is the use of biogeochemical tools, such as the characterization of organic matter, together with ceanographic information. This study used sediment samples from Admiralty Bay, King George Island and analised short cores (25cm) collected at different points inside the Bay and in the Bransfield Strait characterizing granulometry, surface area and the molecular composition of lipids (sterols). A biogeochemical model is proposed to assess the biomarkers variability in function of oceanographic and environmental conditions. The total concentrations of sterols at depths of 100, 300, 500, 700 and 1100 m were 8.5, 17.7, 11.1, 8.3 and 13.4 ug/g, respectively. Phytosterol concentrations are higher in relation to animal sterols at all points collected, indicating a greater contribution of photosynthetic organisms to local organic matter. The variations in concentrations in the localities suggest a different deposition dynamic for each sampled point, mainly in 300m, a region that presented the highest concentrations of total sterols. The variability in hydrographic regimes, ice cover, light, temperature, resurgence zones, climate, physical and chemical factors influence the quantity, quality and origin of the organic carbon that reaches this ecosystem.

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SOOSmap: Southern Ocean data at your fingertips

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Southern Ocean biological and ecological data are scattered and challenging to bring together. However, scientific communities are working to standardise and aggregate observations into useful, circumpolar datasets that can answer broad scientific questions about both process and patterns. The Southern Ocean Observing System (SOOS), as part of its quest to develop a sustainable system of ocean observations, is working to encourage the integration of these datasets. SOOS is committed to helping our community maximise the value of field work in remote areas,

We present SOOSmap (http://www.soosmap.aq/)- a map-based portal where you can filter, query and explore datasets in your browser before downloading just the datasets that you need. SOOSmap is a collaboration between SOOS and the European Marine Observations and Data Network. SOOS is an interdisciplinary community and we are working with a large number of data providers to stock SOOSmap with biological, ecological, chemical, and other datasets.

SOOSmap is the linchpin of our efforts to smooth some of the differences in data sharing cultures among the various scientific disciplines that comprise the SOOS community. The process of negotiating a pathway to make data available through SOOSmap helps find common ground in fundamental issues such as data formats and the balance between the intellectual rights of data producers and the community benefit of making data available for reuse.

SOOSmap is a work in progress and we will share our progress and invite new partners to help us make it work for all Southern Ocean researchers.

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CCAMLR’s challenge in managing the Southern Ocean under environmental change

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Climate change is causing dramatic changes in Southern Ocean ecosystems. The region is experiencing warming, freshening, acidification and reductions in sea ice all with uncertain and complex implications for Southern Ocean ecosystems. The Convention on the Conservation of Antarctic Marine Living Resources demands a precautionary, ecosystem-based approach which includes managing for environmental change. Here we highlight efforts that the Convention's 26-member governing Commission (CCAMLR) has made in managing for climate change. This includes having climate change as an ongoing agenda item, adopting a Climate Change Resolution in 2009 and in 2016 adopting a Conservation Measure towards protecting and studying areas surrounding the Antarctic Peninsula which have experience ice-shelf retreat or collapse. However, in recent years, CCAMLR has struggled to move further and the ongoing threat of climate change and potential overfishing in the Southern Ocean urgently demand more precaution. Efforts to adopt a Climate Change Response Work Plan, to develop climate change implication statements, and to update the outdated 2009 Climate Change Resolution have been met with hard political resistance by some Member States. Meanwhile, CCAMLR has also not created a network of marine protected areas, which can help with resilience to environmental change. Drawing on lessons from around the world, this research highlights best practices for managing marine living resources under climate change scenarios. We close with highlighting CCAMLR’s opportunity for leadership to implement best practices, their responsibility to uphold the Convention and the need to work beyond political barriers in moving towards stronger management action on climate change.

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New challenges to achieve a precautionary and ecosystem management of the krill fishery

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Although the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) has successfully managed fisheries in the Southern Ocean, the observed deep environmental changes, especially in the Atlantic sector, which is the area where krill fishing mainly occur, are imposing new challenges to achieve a precautionary and ecosystem management of the krill fishery. The current catch limits has set over regional scales, overlooking small-scale processes such as the krill availability and predator feeding. Climate-driven contraction of krill distribution, local decrease in krill abundance, recovery of cetacean populations and the potential increase in competition between krill predators and fisheries arise as major concerns that need to be addressed. The increased spatial and temporal concentration of the fleet, coupled with synergistic effects of climate in coastal areas may have impacted penguin populations in years of low productivity. For the first time in more than three decades, fishery-related indicators that had been usually stable, started to show negative trends in last couple of years in some areas that have been persistently used for fishing activities, a warning sign that highlight the need for action. In this regard, environmental monitoring data that can identify increased ecosystem variability associated with climate change, regular acoustic monitoring at multiple scales capable to quantify intra and inter- seasonal krill abundance and flux, and the adoption of MPAs and new spatial regulations (including smaller scales than regional scale) for catches allocation and limits, are key elements in the conservation and ecosystem-based management approach.

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The importance of Antarctic krill in biogeochemical cycles

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Antarctic krill (Euphausia superba) are best known as prey for whales and penguins - but they have another important role. With their large size, high biomass and daily vertical migrations they transport and transform essential nutrients, stimulate primary productivity and influence the carbon sink. Antarctic krill are also fished by the Southern Ocean’s largest fishery. Yet how krill fishing impacts nutrient fertilisation and the carbon sink in the Southern Ocean is poorly understood. In this talk I will present our synthesis which shows fishery management should consider the influential biogeochemical role of both adult and larval Antarctic krill. I will also discuss a new project about to begin linking biogeochemical and ecological numerical models for the Southern Ocean krill ecosystem, and how they can be used to investigate the impacts of climate change and fishing on krill.

1284

What will happen to Southern Ocean ecosystem services in the 21st century?

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The Southern Ocean supports ecosystem services that are important at a global scale. Climate change and the impacts of human activities (fisheries, tourism and scientific research) will affect the demand for, and the provision of, these services into the future. This paper synthesizes recent assessments of the current status and expected future changes in Southern Ocean ecosystems to evaluate the consequences of these changes for the provision of ecosystem services, as part of the first Marine Ecosystem Assessment for the Southern Ocean (MEASO). Based on this synthesis, we provide a high-level assessment of potential direction and magnitude of climate change impacts on ecosystem services. We then use a qualitative network representation to explore the implications of connections and interdependencies. This analysis reveals a complex suite of interdependencies, from changes in climate-related drivers to ecosystem services, including feedbacks across other linked drivers such as fishing. We explore this complexity in detail, focusing on three key services (the Antarctic krill fishery, storage of blue carbon and tourism), tracing the consequences of climate change from physical drivers through to biological impacts and on to the benefits obtained by humans. We relate these to current and future demand for the services, and identify the main global and regional policy frameworks that could be used to manage risks to them in a changing climate. Increased consideration of the linkages and feedbacks between drivers and ecosystem services will be required to underpin robust management responses into the future.

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Oceanic fronts and ecosystems in the Southern Ocean: a review

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A unique aspect of the Southern Ocean's physical environment is that it hosts numerous fronts: sharp boundaries between waters with different characteristics. Fronts are known to be of great importance to the Southern Ocean environment and the ecosystems it supports.

The great advances in biotelemetry tools for animal tracking and the resulting fine-scale animal movement data, coupled with the availability of higher resolution ocean observations from satellites, have recently enabled identification of relationships between marine animals and complex, mesoscale ocean processes. The biota of the Southern Ocean are broadly structured around the principal frontal features of the region: The fronts, by their ability to suppress horizontal exchange of tracers, both create and delimit ecological niches occupied by particular species, supported by water masses with similar characteristics. The challenge for biologists is to integrate observations of animal movements and feeding with the fine-scale physical and biogeochemical properties of Southern Ocean fronts.

Here we review the rapid advances made in understanding Southern Ocean fronts over the last decade and discuss the implications for Southern Ocean ecosystems and the broader climate system. We address the controversy of whether the locations of Southern Ocean fronts have shifted as a result of ongoing climate change, and how the choice of frontal definition can impact the conclusions of a study.

We provide a ‘Southern Ocean fronts User Guide’ aimed at the broader scientific community to facilitate future research with advice on how to best exploit new data and techniques to answer outstanding questions.

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Trends in hydrological, phytoplankton composition and fluorescence parameters in the Pacific sector of the Southern Ocean

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This study investigates changes in surface (<10 m) hydrological, phytoplankton composition and fluorescence parameters measured along a repeated transect over 10 years in the Pacific sector of the Southern Ocean (40-70°S, 130-160°E). Sea surface temperature and salinity values were high in the Subtropical Zone (STZ) and mostly decreased southward. Salinity was very constant in the Polar Frontal Zone (PFZ) region with seasonal and interannual variability less than 0.1. Nitrate, phosphate and silicic acid concentrations increased southward with the lowest values in the STZ. A marked increase in nitrate and phosphate was observed in the Sub-Antarctic Zone (SAZ) and reached maximum values in the Southern Zone (SZ). In contrast, silicic acid concentrations were low (< 3 uM) in the SAZ, with values greater than 5 uM only observed in the PFZ. Chlorophyll concentrations were moderately high (> 0.1 mg/m3) in the STZ and SZ, but low in the PFZ. Microphytoplankton were abundant in the STZ, low in the SAZ and increased southward reaching a peaked (> 80%) south of the AZ. In contrast, there was an opposite trend in the distribution of nanophytoplankton, which had a maximum abundance in the SAZ. Picophytoplankton were abundant in the STZ but decreased southward. Photochemical quantum efficiency of photosystem II (Fv/Fm) varied across oceanic zones, delineated by the fronts. Similar to the trend of the microphytoplankton, high Fv/Fm values were observed in the STZ and AZ is consistent and low in the SAZ and PFZ.

Marine Ecosystem Assessment for the Southern Ocean (MEASO): process, outcomes and strategy for delivery of the first assessment

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The first Marine Ecosystem Assessment for the Southern Ocean (MEASO) aims to provide an up-to-date assessment of the status and trends of marine habitats, species, food webs and ecosystem functioning around Antarctica. The results of the assessment are synthesised to address four challenges for policy makers: (1) maintenance of ecosystem services, (2) identification of areas in the Southern Ocean requiring specific attention, (3) establishing an observing system within the Southern Ocean Observing System (SOOS) that focuses on sentinels of change, and (4) requirements for managing change around coastal Antarctica. The process and outcomes from this assessment will be presented. The strategy for delivering results at the international level to stakeholders, policy-makers and the wider public will be detailed, including using a Summary for Policy Makers (infographics and key messages, e.g. https://twitter.com/MEASO20), on-line resources in the Southern Ocean Knowledge and Information (SOKI) wiki (http://soki.aq/display/MEASO), and the publication of over 20 papers contributing to the assessment in an eBook through the Frontiers in Ecology and Evolution (co-listed in Frontiers in Marine Science, and Frontiers in Environmental Science). The contributions of over 140 marine experts from the Southern Ocean community (including ICED, SCAR, SOOS, CEP, SC-CAMLR, IWC) will be celebrated.

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Measuring krill avoidance behaviour

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Understanding krill avoidance behaviour will help us assess the efficacy of net sampling and contribute to our understanding of krill predator energetics. Here, we examine the effect of fishing on krill swarm structure during and acoustic-trawl survey carried out in East Antarctica. We extend the conventional two-dimensional (depth-distance) view of active acoustics into three dimensions using multi-beam instruments that enable us to observe, rather than infer krill swarm volume, and so sample krill in a manner in line with krill predators. Krill swarm internal density, inter swarm distribution are related to the local current field and examined in three categories: before, during and after fishing.

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What is the sea slug Doris kerguelenensis feeding upon in Deception Island (South Shetland Is., Antarctica)?

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Doris kerguelenensis is an Antarctic heterobranch mollusc feeding on several demosponges and hexactinellid sponges. To assess the contribution of several sponge species to its diet at Deception Island we used stable isotopes of C and N, as well as fatty acids. We examined the demosponges Axinella crinita, Dendrilla antarctica, Hemigellius pilosus, Kirkpatrickia variolosa, Mycale acerata, Sphaerotylus antarcticus, and Haliclona sp. We also analyzed the macroalgae Desmarestia anceps and Himantothallus grandifolius, and phytoplankton. D. anceps was the most 13C depleted one and phytoplankton the most enriched. The δ13C values of sponges and D. kerguelenensis laid in between. The δ15N values of A. crinita, D. antarctica, M. acerata and Haliclona sp. suggested a trophic position between 2-3, and for H. pilosus and S. antarcticus between 3-4. Kirkpatrickia variolosa was in between the two groups. The δ15N values of D. kerguelenensis revealed a trophic position from 3-4. All sponges and D. kerguelenensis had high levels of 15:0 and EPA and low levels of arachidonic acid, largely differing from macroalgae. Fatty acid profiles of A. crinita, D. antarctica, K. variolosa, M. acerata, S. antarcticus, and Haliclona sp. were similar to phytoplankton, but D. kerguelenensis and H. pilosus were enriched in 17:0, 20:1n9 and 20:2. D. kerguelenensis, A. crinita, D. antarctica, K. variolosa, Haliclona sp. and S. antarcticus shared a long chain fatty acid absent in phytoplankton and macroalgae. The overall evidence suggests that A. crinita, D. antarctica, K. variolosa and Haliclona sp. are the most likely prey of D. kerguelenensis at Deception Island.

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Primary productivity and phytoplankton community structure associated with deep chlorophyll maxima (DCM) over the Southern Kerguelen Plateau

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Deep chlorophyll maxima (DCM) occur as distinct peaks of elevated chlorophyll deep within the water column. Despite often being located at depths where light availability is minimal, they can be highly productive and of significant biomass. Their close proximity to deep, nutrient-rich water, may be a possible driver of DCM development. In waters surrounding the Polar Front, high concentrations of silicate and nitrate are believed to support DCMs composed of large diatoms and may contribute to significant carbon and silica flux. However, DCMs are not a persistent feature in the Southern Ocean so their location and biomass cannot be easily predicted or incorporated into models of Southern Ocean productivity. In addition to this, questions still remain about whether phytoplankton cells in the DCM have sunk from surface layer growth or have been entrained there through lateral advection of coastal or sea ice blooms.

An oceanographic and ecological survey (K-Axis) was undertaken during Jan-Feb 2016, over the southern Kerguelen Plateau. In a series of transects, a total of 42 CTD stations were sampled for primary productivity and phytoplankton community composition. A DCM was observed at 24 of these stations, with some comprised of dense diatomaceous mats. Abundant krill, whales and penguins were also observed in these regions. In this presentation, the environmental factors driving the productivity and community composition of DCMs will be assessed. The contribution that DCMs may have on carbon and silica export in this region will also be discussed.

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Primary Productivity Under a Changing Light Environment

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The ability to adapt to a seasonal light regime is one of the most important prerequisites for the Antarctic seaweeds ecological success. Photosynthesis is markedly seasonal in the Antarctic region and persistence of seaweeds depends on their capacity to maintain a positive carbon balance (CB). Principally, the CB is affected by light availability, and a positive CB in Antarctica is only present during the ice-free periods. Studies were performed in Potter Cove, Isla 25 de Mayo/King George Island where climate warming has induced a severe glacial retreat and has opened newly ice free areas. Seaweeds have been colonizing these areas, potentially resulting in higher productivity and carbon sequestration. Photosynthetically active radiation (PAR, 400-700 nm) and CB calculations of key seaweed species were performed over the last decade with the aim of analyzing changes in CB in response to the changing PAR. The glacier melting process during the austral summer resulted in an increased sediment run-off, and a reduced light penetration into the water column, and negative CB values in seaweeds growing in these areas. On the contrary, warmer winters and springs resulted in earlier sea-ice melting, causing increases in the annual light budget and positive CB. Thus, in this study we discuss changes in primary productivity in response to the changing Antarctic light environment and its potential implications for the seaweed community and the rest coastal ecosystem. Finally, these studies require cross-station and international collaboration, as a way to understanding the regional variability in the responses of the biota.

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A neoplasm outbreak in Antarctic fish

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Changing Antarctic climates may place organisms under stressors altering disease resistance. During the 2018 austral autumn, we observed a significant number of crowned notothen (Trematomus scotti) bearing substantial neoplasms. The growths affected approximately 30% of over 200 T. scotti individuals collected by trawling in Andvord Bay, West Antarctic Peninsula. The puffy, pink growths covered about 10-30% of the body surface of affected fish excluding the snout and fins and generally in one contiguous patch, rather than many isolated spots. We also found an individual of another species, the painted notothen (Lepidonotothen larseni), with similar growths in North Dallmann Bay, 90 nautical miles north of Andvord Bay, which with other fjords and bays are hotspots of biodiversity and abundance of fish and other megafauna.

Neoplasia are greatly understudied in Antarctic fish. Antarctic fish researchers we contacted reported either not seeing, or rarely seeing specimens with apparently similar neoplasms. We conclude that similar neoplasms may have existed in Antarctica but not at the magnitude of the outbreak we encountered.

To raise awareness of potential pathogenic outbreaks in Antarctic fish, we will: 1) describe the outbreak we observed, 2) provide evidence on the nature of the pathogenic agent, and 3) disseminate suggestions for collecting and preserving samples for identification of the etiological agent and the diagnosis of any new diseased fish encountered.

With global change affecting the WAP more than any other part of the globe outside the North Pole, it is urgent to assess the potential for dormant pathogens to become infective.

1416

Quantifying the quality of Southern Ocean sponge data for better monitoring, management, and assessment of impacts

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Sponges can be substantial semi-permanent components of benthic polar seafloor habitats, supporting tens of species and thousands of individual seabed animals per m2. They play a key role in ocean nutrient cycling through filtration and blue carbon storage and burial, due to their sporadic fast reproductive and growth responses, large sizes, dominance in many communities, and long life. Good quality temporal and spatial data coverage of sponge species, high-resolution taxonomy, and life processes, is vital in order to better understand sponge diversity and distribution. This will enable meaningful (VME) monitoring and modelling of impacts to sponge communities. This in turn will aid making authoritative decisions in relation to the management and conservation of vulnerable habitats. Southern Ocean sponge data has been reviewed using newly developed quality control information provided by the World Register of Marine Species. This assessment evaluates the current variability in sponge data quality across the Southern Ocean, including taxonomic, spatial, and temporal resolution; the quality of information in differently protected regions; and areas that are currently or in the future, predicted to be undergoing rapid human-mediated and/or climatic changes. Strengths and weaknesses of our current data on sponges are highlighted. Emphasis is placed on the importance of good quality data on sponges for understanding the impacts of current and future climate and/or anthropogenic impacts and management, as well as the potentially increasingly important role that sponges could play in relation to blue carbon feedbacks on climate change, through sequestration on polar seabeds.

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Monitoring 20 years of inter-regional changes in phytoplankton biomass off the Antarctic Peninsula using ocean colour remote sensing

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The marine ecosystems off the Antarctic Peninsula are amongst the most impacted by climate change, particularly by ocean warmth and ice melting. One of the main predicted consequences for marine communities are structural changes to the water column, such as increased stratification. Consequently, changes in the structure and composition of more sensitive biological communities, such as phytoplankton, have already been observed. Due to their vital role as the main marine primary producers, it becomes instrumental to monitor phytoplankton biomass and community changes. However, in-situ sampling in the Antarctic Peninsula is scarce, discrete and, typically, highly limited in time and space. Ocean colour remote sensing (OCRS) can complement in-situ data, enabling a continuous flow of data with good spatiotemporal coverage. While sea ice and cloud coverage are strong limitations, the advent of robust, high-resolution, multi-sensor ocean colour products will contribute to establish OCRS as a tool to monitor phytoplankton in Antarctic waters. This work takes benefit of two robust in-situ (10-year) and remote sensing (20-year) datasets to evaluate changes in phytoplankton biomass. Analyses performed were focused on phytoplankton biomass, uncovering its seasonality and identifying and extracting summer trends and anomalies across the Antarctic Peninsula. Subsequently, specific regions were evaluated through OCRS and compared with the in-situ data collected during summer cruises. Results exhibit significant inter-regional variability, as distinct characteristics and trends were observed. Results are expected to contribute to the existent knowledge on biological communities in the Antarctic Peninsula, establishing OCRS as an essential tool for monitoring the Antarctic ecosystem.

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Springtime rates of coincident inorganic and organic nitrogen and iron uptake across the Atlantic sector of the Southern Ocean

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Southern Ocean phytoplankton are thought to switch from reliance on nitrate to reliance on forms of recycled nitrogen (N) (e.g., ammonium and urea) over the course of the growing season as iron limitation sets in. This switch represents the moment at which the Southern Ocean ecosystem stops sequestering atmospheric CO_2. However, the seasonal evolution of the upper Southern Ocean N cycle is poorly understood, in part due to a scarcity of data from non-summer seasons. To better understand springtime N dynamics, we measured size-fractionated rates of net primary production, N (nitrate, ammonium, urea) and iron (labile inorganic and siderophore-bound) uptake throughout the euphotic zone, and characterized the phytoplankton community at four stations (Marginal Ice Zone, Open Antarctic Zone, Polar Frontal Zone, Subantarctic Zone) during the 2019 Southern oCean seAsonal Experiment (SCALE) cruise. At all stations, picophytoplankton (0.3-3 µm; eukaryotes and prokaryotes) were numerically dominant and cell numbers increased northwards. Carbon biomass was dominated by larger phytoplankton groups, mainly diatoms, with a lesser contribution from dinoflagellates and silicoflagellates. Using our measured rates of coincident N and iron uptake, we can determine the primary N source consumed by each phytoplankton size-class, with implications for their role in the biological carbon pump, and evaluate the strategy of each size-class with regards to iron. These data constitute the first springtime rates of coupled N and iron uptake for the Atlantic sector of the Southern Ocean and should yield insights into the driver(s) of the switch from new to regenerated N dependence by phytoplankton.

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Drift algae accumulation and their important role as ecological subsidies in Antarctica

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Many aquatic communities rely on external subsidies that provide energy and nutrients. Drift algae can function in this way, and in polar regions, the processes producing detached algae and their subsequent accumulation on the bottom can be controlled by ice scouring. Observations made in Fildes Bay (Antarctica) suggest that the local disturbance in shallow soft bottoms by icebergs can produce long and narrow hollows in the seabed (i.e., ice pits). These bottom features tend to accumulate detached macroalgae between depth of 12 and 18 m. These accumulations are usually colonized by conspicuous benthic faunal assemblages. Although drift algae appear to be a major ecological subsidy on soft bottoms in Antarctic, their deposition in ice pits have been poorly described, and their ecological role remains unknown. The objective of this study was to characterize the distribution of drift algae in the subtidal soft bottom habitats in Antarctica and document its importance in creating habitat and driving benthic community diversity. A total of 17 ice pits of 12m2 average area were sampled. A high species richness was observed (16 macroalgae and 25 faunal species) comparable to adjacent benthic rocky reefs. Ice pits thus appear to be key feature of subtidal habitats in soft-bottom regions, where algae accumulated in them provide both habitat and food resources to a surprisingly high biodiversity of invertebrates and are likely important breeding areas for isopods, amphipods and fish. More information is needed o the extent of ice pits and their stability over time.

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Species distribution models for mapping Antarctic Vulnerable Marine Ecosystems: A review of promising methodologies.

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Many taxa that are key components of benthic Antarctic ecosystems are long-lived, have slow growth rates and low productivity. These qualities make them vulnerable to the impacts of bottom fishing and other activities and collectively these taxa form Vulnerable Marine Ecosystems (VMEs). Globally VMEs are the subject of targeted management actions as required by inter alia UN General Assembly resolution 61/105, and in the Southern Ocean under conservation measures adopted by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). However, the VMEs around the Antarctic continental shelf are poorly known, due to the remoteness of Antarctica and the sparsity of observations. Predictive modelling methods, that combine sparse observations with full-coverage environmental data, can fill this gap and provide continuous mapping of suitable habitat or the likelihood of species' occurrences across broad regions of un-sampled seafloor. There are a plethora of analysis methods suitable for predicting the distribution of species. This study reviews and evaluates state-of-art methods with respect to the characteristics of existing VME taxa observations and likely applications of VME predictive modelling. Some of the approaches considered include joint species distribution models, deep learning algorithms, hybrid models and combined data models. Consideration is given to the ability of methods to assimilate rare species, combine data from different sources, appropriately characterise uncertainty and their propensity for over-prediction. Advantages and disadvantages of the approaches are discussed, and candidate methods identified for further investigation using a continent-wide dataset of annotated seafloor imagery and fine-scale environmental predictors.

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Vertical variability in the balance between phytoplankton growth and microzooplankton grazing in the Ross Sea region during summer and early-autumn

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The Ross Sea region is one of the most productive areas of the Southern Ocean. The fate of primary production depends critically on the balance between phytoplankton growth and loss rates, which are poorly constrained. In this study we measured growth and microzooplankton grazing rates during two voyages conducted in February-March (2018) and January-February (2019) in oceanic waters off the continental shelf. We conducted dilution grazing experiments at six depths within the euphotic zone to investigate the variability of growth and grazing rates with vertical physico-chemical gradients including irradiance. This depth-resolved approach provided the first parallel estimates of water-column integrated phytoplankton production, consumption and accumulation rates in the Ross Sea region. Growth rates were higher than grazing in the surface mixed-layer, and tended to decrease with depth, while grazing rates remained relatively constant vertically. This resulted in a net accumulation of phytoplankton in the surface mixed-layer that reversed into net consumption below a certain depth. This 'compensation' depth varied among stations. Vertical variability was more evident in the 2019 than the 2018 campaign conducted later in the season and when growth rates were lower (µ.2019 = 0.32±0.19 day-1 , µ.2018 = 0.08±0.11 day-1) and more tightly balanced by grazing (µnet.2019 = 0.25±0.17 day-1 , µnet.2018 = -0.11±0.34 day-1). Understanding the factors that control phytoplankton growth, microzooplankton grazing, and the balance between these rates is crucial to predict the effects that projected environmental changes will have on the trophic and biogeochemical functioning of the Ross Sea region pelagic ecosystem.

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What over 20 years of sediment trap data can tell us about ecosystem variability

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Our understanding of temporal variability in the Southern Ocean ecosystem is hampered by logistical constraints that come with working in this remote region of the planet. One solution for this problem is automated moorings; for example, at the Southern Ocean Time Series site (SOTS) at 47˚ S in the subantarctic. Sediment traps have been deployed at the mooring site since 1998, located at different depths below the mesopelagic zone to measure the variability in sinking organic carbon flux. These devices also collect “swimmers”; live zooplankton swim into the traps and are killed by preservative but are subsequently separated from the smaller size fraction of passively sinking particles. Zooplankton play an important role in the food web as they transfer energy from phytoplankton to higher trophic levels including fish and marine mammals. Due to their short life span, they are sensitive to environmental change and used as an indicator of the structure and health of the Southern Ocean ecosystem. Here, we will present a look at this zooplankton time-series with a focus on the main groups, i.e. copepods, amphipods, pteropods, chaetognaths and ostracods in relation to carbon flux and environmental drivers such as temperature. With this important time series, we can increase our understanding of seasonal and inter-annual variability of plankton composition and identify environmental drivers responsible for community shifts. Finally, we can predict future changes in ecosystem functioning that can inform conservation and management decisions in the subantarctic Southern Ocean.

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Effects of ocean acidification on Antarctic marine organisms: a meta-analysis

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Southern Ocean waters are amongst the most vulnerable to ocean acidification. The projected increase in the CO_2 level will cause changes in carbonate chemistry that are likely to be damaging to organisms inhabiting these waters. A meta-analysis was undertaken to examine the vulnerability of Antarctic marine biota occupying waters south of 60°S to ocean acidification. This meta-analysis showed that ocean acidification negatively affects autotrophic organisms, mainly phytoplankton, at CO_2 levels above 1000 µatm and invertebrates above 1500 µatm, but positively affects bacterial abundance. The sensitivity of phytoplankton to ocean acidification was influenced by the experimental procedure used with natural, mixed communities being more sensitive than monospecific cultures. Invertebrates showed reduced fertilization rates and increased occurrence of larval abnormalities, as well as decreased calcification rates and increased shell dissolution with any increase in CO_2 level above 1500 µatm. Assessment of the vulnerability of fish and macroalgae to ocean acidification was limited by the number of studies available. Overall, this analysis indicates that many marine organisms in the Southern Ocean are likely to be susceptible to ocean acidification, thereby likely changing the ecosystem structure and dynamics of the Southern Ocean in the future with significant ramifications for not only the Southern Ocean but also the feedbacks it has to global climate change.

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Effects of iron chemistry for its bioavailability and impact on primary producers and microbial and viral community in contrasting Southern Ocean provinces

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Organic ligands such as carbohydrates and exopolymeric substances (EPS) are known to complex with iron (Fe) and influence its bioavailability to phytoplankton. In this work, we addressed how Fe enrichment associated to organic binding ligands influences Fe chemistry as well as its bioavailability and productivity for phytoplankton, and microbial dynamics in the Drake Passage and the West Antarctic Peninsula. At each station, we performed short-term (24h) and long-term (6d) shipboard incubations with the in-situ microbial community before (control treatment) and after addition of different Fe-binding ligands (total Fe added 0.9 nM), including: the siderophore desferrioxamine B, two carbohydrates (glucuronic acid and carrageenan) and two different bacterial exopolycarbohydrates (L6 and L22, referred as EPS). Our results showed significant correlations between Fe uptake rates and the measured inorganic Fe concentrations, a form that is known to be bioavailable. Better correlation was obtained for larger phytoplankton considering labile Fe concentrations, suggesting that this chemical fraction could be an interesting parameter to estimate Fe bioavailability to large plankton assemblages, relevant to carbon export in the Southern Ocean. Moreover, iron bioavailability was correlated to primary productivity for the 2 Drake Passage sites, suggesting that iron chemical speciation could be used as a first level predictor for productivity in this region. In contrast, more complex parameters are involved in the control of microbial and viral communities, with carbon availability as a potential important driver.

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Importance of refractory ligands and their photodegradation for iron oceanic inventories and cycling

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Iron is an essential micronutrient that limits primary production in up to 40% of the surface ocean and influences carbon dioxide uptake and climate change. Dissolved iron is mostly associated with loosely characterized organic molecules, called ligands, which define key aspects of the iron cycle such as its residence time, distribution and bioavailability to plankton. Models based on in-situ ligand distributions and the behaviour of purified compounds include long-lived ligands in the deep ocean, bioreactive ligands in the surface ocean and photochemical processes as important components of the iron cycle. Herein, we further characterize biologically refractory ligands in dissolved organic matter (DOM) from the deep ocean and labile ligands in DOM from the surface ocean and their photochemical and biological reactivities. Experimental results indicate that photodegradation of upwelled refractory iron-binding ligands can fuel iron remineralization and its association with labile organic ligands, thus enhancing iron bioavailability in surface waters. These observations better elucidate the roles of biologically refractory and labile molecules and global overturning circulation in the ocean iron cycle, with implications for the initiation and sustainment of biological activity in iron-limited regions and the residence time of iron in the ocean.

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Coupling environmental drivers to the composition and production of the phytoplankton community in the Ross Sea during summer 2018 and 2019.

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The Ross Sea is one of the most productive regions of the Southern Ocean with an elevated net primary productivity (NPP) in spring-summer that fuels the food-web dynamics and sink of atmospheric CO2. As warming is prominent in the Southern Ocean, the changing environment will ultimately determine phytoplankton contribution to trophic and biogeochemical cycling in the Ross Sea. Samples of primary productivity and microbial community composition were acquired during two cruises conducted across the slope and oceanic region of the Ross Sea during February-March 2018 and January-February 2019. Phytoplankton biomass and composition were examined through the analysis of total and size-fractionated chlorophyll-a, flow-cytometry, microscopy and pigments quantified by High-Pressure Liquid-Chromatography and CHEMTAX. Primary productivity rates were estimated from 24-h 14C-incorporation incubations conducted with seawater collected at 6 discrete depths. Short-term Photosynthesis-Irradiance experiments were performed in parallel and daily water-column productivity calculated from estimated photosynthetic parameters. Chlorophyll a concentration was lower during 2018 (range = 0.025-0.45 mg/m3) compared to 2019 voyages (range = 0.25-2 mg/m3) yet, mostly allocated in the >20-um fraction during both campaigns. The community was dominated by diatoms and prymnesiophytes that often made up over 80% of total chlorophyll. NPP tended to be higher in 2019 compared to 2018. Depth-resolved NPP tended to be lower in 2018 (3 to 12 mgC/m3/day) compared to 2019 (3-25 mgC/m3/day) that occurred later in the season. The relation between oceanographic conditions, phytoplankton community composition and production estimated with different approaches is discussed in the context of projected environmental changes for the region.

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Detecting, attributing and mapping ecological change in the Southern Ocean using joint species distribution models.

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The Southern Ocean supports exceptional biodiversity and productive and distinctive ecosystems as well as providing a range of critical ecosystem functions. The physical environment of the Southern Ocean has changed over the last 30 years and will continue to do so on a time scale of decades. However, a basic understanding of whether, how and why entire assemblages of species have changed, and are likely to continue to change, in response to environmental and other factors is lacking for most levels of the ecosystem. Here we examine key ecological time series data of demersal fish on the highly productive Kerguelen Plateau. We use the latest developments in spatio-temporal joint species distribution modelling to detect, quantify and map species and assemblage-level changes. Preliminary results will be presented on which species have responded to environmental and other changes, what factors are important in driving these changes, and which areas of the plateau are undergoing the greatest change. We will also discuss what we have learnt thus far in applying these relatively new models and how this information feeds into management initiatives.

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Investigating the impacts of environmental variability on the Kerguelen Plateau Patagonian Toothfish fishery using spatio-temporal models

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The Kerguelen Plateau is a large, isolated submarine plateau in the southern Indian Ocean. The plateau is home to a significant Patagonian toothfish fishery, worth over USD50 million a year in the Australian sector alone, as well as being home to significant populations of seals, seabirds and whales. In 2016, the Australian longline fishery on the Kerguelen Plateau experienced lower than average catch rates. At the same time, the Kerguelen Plateau experienced a surface heatwave. A preliminary investigation concluded that the declining catch rates were unlikely to be caused by a decline in fish stock biomass, but instead could have been related to a change in fish catchability driven by environmental factors. Here we examine the influence of environmental variability on Toothfish catch rates over the last 20 years at both a coarse and fine spatial resolution. We combine the outputs from satellite products and oceanographic models with detailed catch data using spatio-temporal models. We present preliminary analysis and discuss how much of the variability in catch rates can be attributed to environmental factors, which factors are relatively important and map a time series of spatial changes in catch across the plateau. We also discuss the implications of these models for predicting environmental impacts on future catch and for management within the fishery.

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Sediment load, iron and macronutrients in icebergs: their relationship and its implications for Antarctic coastal waters

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The sediment load of Antarctic icebergs varies five orders of magnitude from a few mg of sediment per liter to more than 10 g L-1. Similarly, the concentration of total dissolvable iron TdFe (i.e. particulate plus dissolved iron dFe) in Antarctic icebergs spans six orders of magnitude, while the dissolved phase only varies three. Iron fractions are more abundant in icebergs than in Antarctic seawater, indicating the potential fertilizing effect of icebergs in the Southern Ocean. The concentration of N, P and Si in icebergs is two orders or magnitude lower than Southern Ocean waters, pointing out to the possibility of a dilution effect of the macronutrients in areas where melt-water outflow is intense. Besides, when large amounts of sediments are released into coastal waters it can have a negative effect on phytoplankton and zooplankton due to shadowing and disruption of feeding respectively. Higher sediment load of individual icebergs was related only to higher TdFe, whereas the other parameters (i.e. dFe, N, P and Si) did not show any significant relationship. This implies that icebergs with higher sediment load present more iron (TdFe), but does not transform directly into its more bioavailable form (dFe). In summary, higher sediment load will have more severe effects on plankton without providing more nutrients (dFe, N, P or Si) to coastal waters. Therefore, under future freshening and glacier retreat scenarios, where icebergs may carry higher sediments load, their fertilizing effect may be similar while the negative effects on phyto- and zooplankton may become stronger.

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Evaluation of Iron Sources in the Ross Sea

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A one-dimensional numerical model that includes the complex life cycle of Phaeocystis antarctica, diatom growth, dissolved iron (dFe) and irradiance controls, and the taxa's response to changes in these variables is used to evaluate the role of different iron sources in supporting phytoplankton blooms in the Ross Sea. Simulations indicate that sea ice melt accounts for 20% of total dFe inputs during low light conditions early in the growing season (late November-early December), which enhances early blooms of P. antarctica. Advective inputs of dFe (60% of total inputs) maintain the P. antarctica bloom through early January and support a diatom bloom later in the growing season (early to mid-January). In localized regions near banks shallower than 450 m, suspension of iron-rich sediments and entrainment into the upper layers contributes dFe that supports blooms. A seasonal budget constructed from the simulations shows that uptake by P. antarctica (solitary cells and colonies) accounts for the largest sink of dFe, with uptake by diatoms being the second largest sink. Remineralization of detritus by bacterial processes is the largest biological source of dFe. Sensitivity studies show that surface input of dFe from sea ice melt, a transient event early in the growing season, sets up the phytoplankton sequencing and bloom magnitude, suggesting that the productivity of the Ross Sea system is vulnerable to changes in the extent and magnitude of sea ice.

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Machine learning for predicting marine invasive species in the Southern Ocean: a case study of the Australian Antarctic and subantarctic regions

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Marine invasive species (MIS) have established around every continent on Earth, except Antarctica. Changes in the climate have the potential to open Antarctic waters to the threat of MIS introduction. We use a novel machine learning algorithm to predict which currently known MIS could survive in shallow benthic ecosystems adjacent to Australian Antarctic research stations and subantarctic islands, where ship traffic is present and represents the most likely pathway by which MIS will arrive via hull fouling. We used gradient boosted machine learning (XGBoost) with four important environmental variables (sea surface temperature, salinity, pH, and nitrate) to develop models of suitable environments for each potentially invasive species. We then used these models to determine if any of Australia's three Antarctic research stations and two subantarctic islands could be environmentally suited for MIS now and under two climate change scenarios. Both seasonal and annual models indicate that the predatory sea star Asterias amurensis is a current and ongoing threat to all locations under both climate change scenarios (except Casey presently under the seasonal model). Up to 13 other species were also shown to be a risk, however the results were sensitive to the model used. Due to their isolation, endemic Antarctic benthic ecosystems are ill-prepared to cope with novel species. These endemic communities are already under threat as a result of climate change, and the addition of MIS could cause irreversible damage to these ecosystems.

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Projected shifts in the foraging habitat of crabeater seals along the Antarctic Peninsula

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The crabeater seal exhibits one of the most extreme levels of dietary specialisation in mammals, feeding almost exclusively on Antarctic krill, inextricably linking the habitat use, life history, and evolution of this pinniped species to the distribution of its prey. We combined seals' movement and diving behaviour data with environmental variables to build a habitat model for crabeater seals (and putative krill distribution) from the fast-changing western Antarctic Peninsula (wAP). Projections for the future indicate that the foraging habitat of crabeater seals and inferred krill distribution will expand toward offshore waters and the southern sectors of the wAP, as a consequence of warming temperatures and changes in sea ice distribution. As krill biomass will likely be negatively affected by environmental changes, it follows that this expansion will result in a decrease in krill densities. These changes will have implications for land/ice based krill predators, such as seals and penguins, particularly in the northern wAP, the Scotia Sea, and the South Georgia Islands, as these areas depend on krill inputs from the central wAP to support the krill population.

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A Closed, Subsurface Eddy Increases Residence Times within Palmer Deep Canyon

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Palmer Deep Canyon is a biological hotspot along the Western Antarctic Peninsula. The observation of persistent hotspots in association with submarine canyons along the peninsula has led to the 'canyon hypothesis' which relates local geological and physical oceanographic features to the hotspots. Historically, the upwelling of nutrient-rich Upper Circumpolar Deep Water to the surface mixed layer in the submarine canyon was thought to drive biological productivity, attracting krill and penguins to the region. However, recent observations of low surface residence times, lack of Upper Circumpolar Deep Water in the surface layer, and abundant surface nutrient concentrations at Palmer Deep Canyon have called the upwelling mechanism into question.

Sloped isopycnals and a subsurface particle layer observed over the canyon by three Slocum gliders in 2015 suggest the presence of a deep subsurface eddy. Neutrally buoyant particle simulations using the Regional Ocean Modeling System with 1.5 km horizontal resolution were used to test the hypothesis that residence times increase with depth within the canyon. Particles were seeded on a 4 km horizontal grid, every 2 days, at several depths over a 6-month simulation period in two austral summers. These simulations suggest that the deep eddy increases residence times and is the most coherent during the austral summer. In-situ images and water samples from the subsurface particle layer observed in 2015 and 2020 suggest that small detritus particles are retained within the canyon. These seasonal, retentive features of Palmer Deep Canyon could be critical to the establishment of the biological hotspot.

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Status, change and futures of zooplankton and krill in the Southern Ocean

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Zooplankton play an important role in global marine ecosystems. In the Southern Ocean, zooplankton represent the largest proportion of biomass and perform a number of vital ecosystem functions. They are involved in sustaining an array of diversity and marine life, functioning as grazers of primary production, as predators, as prey of commercially valuable species (including fish and Antarctic krill) and higher trophic levels (including seabirds and marine mammals), biogeochemical cycling and provisioning international fisheries. Global change is expected to affect the structure and function of zooplankton assemblages in the Southern Ocean, which will have wide ranging implications for the ecosystem and the services they maintain. As a contribution to the Marine Ecosystem Assessment of the Southern Ocean, we review the current understanding of zooplankton assemblages within the Southern Ocean, with a particular focus on key taxa including. We provide an overview of observed and potential future responses of these communities to global change. We also explore areas of future research that can underpin robust projections of changes in these taxa across the Southern Ocean.

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Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme

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The Integrating Climate and Ecosystems Dynamics in the Southern Ocean programme (ICED) is an international multidisciplinary programme focused developing integrated circumpolar analyses of Southern Ocean climate and ecosystem dynamics. ICED is a co-sponsored programme of the Scientific Committee on Antarctic Research (SCAR). ICED was developed with the support of SCAR, in conjunction with the Scientific Committee on Oceanic Research (SCOR), and the International Geosphere-Biosphere Programme (IGBP) and is a regional programme of Integrated Marine Biosphere Research (IMBeR). ICED is focussed on understanding the climate interactions in this globally important ocean, the implications of change for ecosystem dynamics, and the impacts on biogeochemical cycles. These aspects are crucial for supporting conservation and sustainable management approaches and evaluating the role of Southern Ocean ecosystems in the Earth System. ICEDs priority research areas over the coming years include 1) understanding and quantifying the state and variability of Southern Ocean ecosystems, 2) improving scenarios and projections of future Southern Ocean ecosystems at multiple scales, and 3) supporting sustainable Southern Ocean governance. ICED will also remain open to emerging ideas, new analytical approaches and technologies as aspects of Southern Ocean climate, ecosystem and biogeochemistry research progress. ICED will also continue to coordinate and develop a range of planned national fieldwork campaigns, foster integration through capacity development and outreach, and ensure alignment of our activities with other international research programmes. We encourage wide participation in the research goal and objectives of the ICED programme.

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Lowered cameras reveal hidden seasonal and diel shifts in krill behaviors and vertical distributions

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For decades, Antarctic krill were considered to spend their adult lives occupying epipelagic depths. These surface layers form the focus of stock surveys crucial for fisheries management. However, recent research has revealed significant parts of the krill population are found deeper, often near the seabed, throughout the year. Using >125 hours of video observations of krill collected by a camera system profiling the entire water column, up to depths of 625m, along the Western Antarctic Peninsula during two seasons, we were able to quantify seasonal and diel krill vertical distributions and behaviors which have remained hidden from traditional survey methods. Our results suggest that most krill observed were either at depths too deep (i.e., < 200m) or densities too low (i.e., < 2 krill m-3) for traditional survey methods to detect. We can explain seasonal shifts in krill vertical distributions through changes in individual krill movement behaviors, which provides mechanistic insight and predictive powers. These individualized observations revealed krill were faster in late spring than autumn and were feeding primarily in the water column in spring and at the seabed in autumn. Besides presenting video footage of these krill behaviors, we will demonstrate the results through simulations of krill vertical distributions and energetic requirements from measured krill vertical velocities and swimming speeds. These observations provide quantitative insights into the role of krill in pelagic and benthic food webs and vertical nutrient fluxes, as well as for conducting stock surveys which underpin krill fishery management.

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Krill biomass survey for krill monitoring and management in CCAMLR Division 58.4.2-East

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Australia plans to conduct an Antarctic krill biomass survey in CCAMLR Division 58.4.2 East (50-80°E) from 23rd January to 25th March 2021, using the Marine National Facility RV Investigator. Historical fishing patterns suggest that future fishing grounds will likely form to the east of the 50°E meridian in the Indian Ocean Sector, which is within the target area of this survey. This area was last surveyed in its entirety fourteen years ago, therefore, by using the survey results we will update the krill biomass estimate with a view to revising the precautionary catch limit for krill in this area. Three krill observatory mooring systems will also be deployed during the survey to enable long-term monitoring of krill dynamics within the seasonal ice zone. The survey is also designed to improve our understanding of the connectivity of krill populations, and the overlap between krill and predator populations. Information obtained through the voyage will support design a tractable and sustainable long-term monitoring plan and spatial management of the krill fishery in East Antarctica. We will present an overview of both the voyage plan and how the information obtained from the voyage will be used to inform krill fishery management.

550

A data-model comparison of marine primary productivity in the Last Glacial Maximum and the Last Interglacial

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We present a data-model comparison of marine primary productivity in the Last Glacial Maximum (LGM; 21,000 yr BP) and the Last Interglacial (LIG or marine isotope stage 5e; 127,000 yr BP), focusing particularly on the Southwest Pacific and the Southern Ocean. These two time slices represent a colder-than-present (LGM) and a warmer-than-present (LIG) climate, allowing us to evaluate the model's ability to represent contrasting climates. The simulations are run using the intermediate-complexity UVic ESCM v2.9, modified to include a calcifying plankton functional type and a prognostic iron cycle. We evaluate the model skill using the anomaly from a pre-industrial control simulation. Key metrics include surface air temperature, sea surface temperature, sea ice extent in the Southern Ocean, plankton biomass and net primary productivity (NPP), and sediment CaCO3 content. We focus on the relative change in marine ecosystems and primary productivity (both abundance and distribution) over glacial – interglacial timescales and infer what this could mean for future change over the next century.

1594

A comparison of estimations of net community production in the Amundsen Sea polynya, Antarctica

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In Antarctic Polynya, where productivity is known to be high, it is important to estimate NCP accurately to understand the marine carbon cycle and further air-sea CO_2 flux by biological pumps. We used the difference of dissolved inorganic carbon (DIC) contents in the water column between the surface water and underneath the mixed layer deep water to determine NCP assuming that the deep water preserves the winter characteristics of dissolved inorganic content. This is true in the Amundsen Sea polynya (ASP) as the winter water is detected below the mixed layer. Various literature shows ambiguous definition of the reference depth between the surface and deep waters. We estimated NCP in the Amundsen Sea polynya applying various reference depths relevant to the biological production and vertical mixing. We employed the results from the expedition conducted in ASP during austral summer in 2011. Five reference depths were selected to represent the winter water for which biological activity paused; (1) potential temperature minimum depth (pTmin), (2) euphotic depth (Ed), (3) mixed layer depth (MLD), and (4) 100 m and (5) 200 m nominal depths. The ratio of DIC to total alkalinity (DIC/TA) was altered by biological activities in the surface water. When the DIC/TA ratio is close to the value of deep water, it closely matches the pTmin of the reference depth. The NCP is estimated using this method, 94 ± 43 mmol C/m^{2}d (n=11) in the Amundsen Sea polynya.

1249

Project SWARM: An integrated polar ocean observing system mapping the physical mechanisms driving a food web focused on an Antarctic biological hotspot

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The physical mechanisms that maintain and deliver phytoplankton and Antarctic krill biomass, potentially increasing prey availability to predators, are not well understood. For example, the short surface ocean residence time of 1-2 days over Palmer Deep is in conflict with the prevailing hypothesis that local growth supports phytoplankton at the base of the food web. Coincident measurements of phytoplankton, prey fields, and predator locations in their advective context are being made to establish the ecological importance of horizontal flow. To better understand these important mechanisms, we have deployed an integrated polar observatory consisting of high frequency radar, coordinated gliders, small boat surveys, and moorings. This integrated polar observatory enables us to simultaneously sample across the entire food web from the phytoplankton and prey fields to the top predators to understand the ocean features that support life in these polar systems. For the first time in this region, we have: 1) integrated sensors and technologies to simultaneously map phytoplankton blooms, krill aggregations, and top predator foraging relative to dynamic ocean features; 2) integrated these observations with a high-resolution (1.5 km) 3-D dynamic model simulation of the entire WAP coastal ocean to generalize our field measurements to other known hotspots along the WAP through simulation, and analyzed which physical mechanisms lead to the maintenance of these hotspots. Instead of local upwelling, we find that horizontal dynamics and tidal flows are more important to maintain these biological hotspots.

683

Fish parasites as indicators of the state marine ecosystems in West Antarctic: parasite community of Notothenia coriiceps as an example.

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Environmental changes caused by the global warming and anthropogenic factors observed around the world are the most pronounced in Polar Regions. The aim of our study was to analyze the role of metazoan parasites of rock cod Notothenia coriiceps as potential indicators of marine ecosystem state of the Argentine Islands Archipelago, West Antarctica. The study was performed in 2014–2015 at the Ukrainian Antarctic station "Akademik Vernadsky". Totally more than 8,500 specimens of helminths were collected from 106 specimens of N. coriiceps and identified.
All fishes (100%) were found to be infected with helminths; 24 helminth species were identified. Eight species of acanthocephalans were recorded in 96.4% of fish with mean intensity (MI) 25.3. Five species of nematodes were found in 96.2% fishes; MI=14.8. Seven species of digenean trematodes were found in 94.3% of fishes; MI=33.7. Larval stages of cestodes were registered in 78.7% of fish; MI=10.3. Comparison of our data with the results of previous studies performed at the "Akademik Vernadsky" station in 2002 with the same methods (Zdzitowiecki, Laskowski, 2004) revealed significant changes in structure of the parasite community of N. coriiceps. Prevalence and abundance of six helminth species have changed in 3–20 times during last decade; the most prominent changes were documented in trematodes and cestodes with complex life-cycles which include 2–3 intermediate and paratenic hosts. In our opinion, these six species can be considered as potential indicator species for future monitoring studies of ecological and environmental changes in the Antarctic coastal and marine ecosystems.

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Calving event modifies bloom phenology in the Mertz polynya

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Polynyas are areas of open waters surrounded by ice. They are subject to variability in winds and ocean circulation and are important sites of ecological productivity. In February 2010, the B09B iceberg collided with the Mertz Glacier Tongue, calving a 78x40 km giant iceberg which modified the entire icescape and primary productivity of the Mertz Polynya. In this study, we use satellite-derived ocean color and sea ice remote sensing to investigate the inter-annual variability trends and drivers of phytoplankton in the Mertz polynya over the past 21 years, with a focus on contrasting the pre-calving (1997 – 2010) and post-calving (2010 – 2018) periods. During the bloom period, we found so far: (i) an increase in sea-ice concentration, (ii) a later bloom start, (iii) a later ice-retreat time and (iv) a decrease in bloom duration. We attribute these results to the post-calving period, which clearly drove the trends in this study. The calving event resulted in significantly higher chl-a concentration, higher sea-ice concentration and lower sea surface temperature. Our results suggest a clear relation between the phytoplankton bloom and the sea-ice phenology. While satellite data are a useful tool to study long term variability in inhospitable areas like the Southern Ocean, we highly recommend the deployment of in situ platforms such as biogeochemical Argo floats in polynyas. The additional parameters would strengthen our comprehension of phytoplankton and physics changes that may have consequences for global circulation, carbon export, primary production, and higher trophic levels.

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Zooplankton community structure and dominant copepod population structure on the southern Kerguelen Plateau during summer 2016

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The influence of environmental factors on the horizontal community structure of zooplankton over the southern Kerguelen Plateau was investigated during summer in 2016. Zooplankton abundance ranged from 1,490 to 363,484 ind. 1000 m-3, with highest numbers observed in the eastern and central areas. Based on cluster analysis the zooplankton were divided into 6 groups (A−F), although their distribution was not definitively associated with water masses and frontal systems. Groups A to C had abundant zooplankton and were consistent with areas of high chlorophyll a concentration. Group D represented low abundance near the southern Antarctic Circumpolar Current front, while group E was clustered south of the Southern Boundary and group F comprised two stations to the east of the Fawn Trough. General linear modelling (GLM) highlighted both fronts and primary production as drivers of overall zooplankton distribution. This was not the case for drivers of population structure of key species, a result of species-specific life history strategies.

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Oceanographic processes and biological responses around the Northern Antarctic Peninsula: the case of cryptophytes.

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The Northern Antarctic Peninsula (NAP), which encompasses the Bransfield Strait, the southernmost section of the Drake Passage, the northwestern Weddell Sea and the region north of the Western Antarctic Peninsula (WAP) shelf, is primarily important because of the evolving changes on ecosystems and ocean-atmosphere-cryosphere dynamics related to climate change issues. The Brazilian High Latitudes Oceanographic Group (GOAL) was formed in 2002 within the scope of the Brazilian Antarctic Program (PROANTAR) aiming to contribute to the understanding of the relationship between the marine biota, from microorganisms to top predators of the Southern Ocean food web, and the physical-chemical environment. For 15 years, we have been studying the ecology of the phytoplankton community around the NAP. We have observed that cryptophytes are gradually outgrowing other phytoplankton groups (e.g. diatoms and Phaeocystis antarctica) in areas under the influence of both sea-ice and glacial melting processes. Under such conditions, very shallow upper mixed layer depths confine cryptophytes near the surface (0–25 m), exposing them to high irradiance. This study shows that the recurrent growth and dominance of cryptophytes in the NAP region can be attributed to their unique abilities not only to grow at low micronutrient conditions, but also to thrive under extreme light levels normally found in confined stratified upper layers in summer. Such conditions are becoming more frequent and intense in NAP coastal waters and will probably have significant implications for the primary producers' community structure and, therefore, to the regional food web and biodiversity patterns in the region.

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Variability and adaptation of Phytoplankton community in the frontal zones of Southern Ocean

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Phytoplankton biomass (chlorophyll-a) and community in the water column were analyzed in various frontal regions in the Subtropical front (STF), Sub-Antarctic front (SAF), Polar Front-1 (PF1) and Polar Front-2 (PF2) in the Indian Ocean sector of the Southern Ocean (SO) during the austral summer (January-February) of 2013 and 2015. The surface chlorophyll-a (Chl-a) was maximum in PF1 (0.77 mg m-3) followed by the SAF (0.5 mg m-3), STF (0.26 mg m-3) and PF2 (0.21 mg m-3) in 2013. The Chl-a was maximum in the SAF (0.56 mg m-3) followed by PF1 (0.32 mg m-3), PF2 (0.28 mg m-3) and STF (0.20 mg m-3) during 2015, suggested that the average surface biomass along the track was higher in 2013. The deep chlorophyll maximum (DCM) was located at 50 m in STF and SAF for 2013 and 2015. However, it was found at 75 m (100 m) in PF1 (PF2) during 2013. Diagnostic pigment index indicated the Diatoms in the surface and water column increased from the STF to PF. In contrast, the community Flagellates and Prokaryotes were decreased from the STF to PF. The Flagellates were uniformly distributed throughout the water column. The Prokaryotes were homogenously distributed up to the DCM level and then progressively declined towards the deeper region. The nitrate, phosphate and silicate were increased considerably from the STF to PF through SAF. Results indicate the biomass and community variation in the frontal regions were due to the influence of physical, chemical, and biological processes in varied environmental conditions

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Overview of the results of the multidisciplinary marine ecosystem survey in the Indian sector (80-150°E) of the Antarctic during 2018/19 season by the Japanese survey vessel, Kaiyo-maru

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A multidisciplinary ecosystem survey in the eastern Indian sector of the Antarctic (80-150°E) was carried out by Kaiyo-maru during the 2018/19 season for 53 days. RMT tows were carried out at 72 stations. SUIT tows were carried out at 28 stations. Quad NORPAC tows were carried out at 44 predetermined stations. Narrowband echosounder data to estimate biomass of Antarctic krill were recorded along predetermined tracklines for 2,519 n.miles. Broadband echosounder data were recorded at 24 targeted RMT stations to estimate length distribution and swimming angles of Antarctic krill acoustically. SADCP and PDR data were continuously recorded along the tracklines. A total of 101 CTD and 150 XCTD casts were made for physical and chemical oceanographic studies. Six types of autonomous profiling floats and buoys were deployed at 18 locations. Surface oceanographic environment data were continuously recorded along the tracklines. Sea ice (18 samples) and iceberg (15 samples) were collected for physical and chemical oceanographic studies. A total of 26 CTD casts were made for biological oceanographic studies. A total of 339 schools with 552 individuals of marine mammals were sighted during 1,249 n.miles of sighting effort along the tracklines. A total of 8,616 individuals of seabirds were sighted during 1,257 n.miles of sighting effort along the tracklines. Biological video recordings were made 25 times using 6 types of video recording devices. A number of detailed analyses using obtained samples and data are in preparation and the results will be presented to the Antarctic scientific community.

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Summer krill availability in Adélie and gentoo penguin foraging areas south of Anvers Island

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The Palmer submarine canyon, located south of Anvers Island along the West Antarctic Peninsula, is a biological hotspot with high primary productivity, abundant krill, and Adélie and gentoo penguin rookeries. Many studies have focused on physical mechanisms that spur the canyon's productivity, and foraging behaviors of the local penguin populations. However, little is known about krill distribution and abundance within the canyon. Palmer Station's recent acquisition of an EK80 120kHz echosounder and small boats capable of traveling further afield presented an opportunity to fill this gap in understanding. Our study focused on the physical and biological drivers of summer krill availability in two major penguin foraging areas. Survey grids were designed in recurrent Adélie and gentoo foraging areas based on 10 years of penguin satellite tag data. These acoustic surveys were run weekly from January to March and included cross-shelf CTD casts measuring temperature, salinity, and fluorescence. Results showed an increase in krill biomass from January to March independent of the peak phytoplankton bloom, indicating an inshore summer krill migration due to life history rather than food availability. Krill aggregations were mostly found near shallowing bathymetry including canyon walls and seamounts. Aggregations were significantly deeper in the gentoo foraging area than in the Adélie, concurrent with penguin foraging dive depths in each area. The mean depth of krill aggregations deepened through the summer, decoupling from the depth of the chlorophyll maximum in March. This study provides a baseline understanding of krill availability in penguin foraging areas undergoing significant environmental change.

1475

A community-driven Southern Ocean contribution to the UN Decade of Ocean Science for Sustainable Development

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The UN Decade of Ocean Science for Sustainable Development 2021-2030 presents a once-in-a-lifetime opportunity to deliver scientific knowledge, foster technological innovation, and build capacity to achieve the 2030 Agenda and reverse the decline of ocean health. The Southern Ocean community will combine efforts to contribute to the UN Decade of Ocean Science, through leverage of existing efforts and development of new initiatives and partnerships where possible.

The first planning workshop for the Southern Ocean contribution was held in February 2020 and was the first step towards identifying the potential scope of a Southern Ocean contribution to this global initiative. Building on these initial discussions, the community is now invited to engage in drafting a strategy for implementation, structured around 6 UN Themes of societal deliverables and 5 Cross-Cutting Themes. This presentation will provide an overview of the key outcomes of the first Planning workshop, and propose a way forward that enables full community engagement and collaboration across industry, research, monitoring, policy and nations.

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Glacial Discharge and its Impact on Phytoplankton Community Composition in an Western Antarctic Fjord and Continental Shelf

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The impact of ice-ocean interaction on the Southern Ocean is expected to intensify in the future. However, the influence of glacial discharge on phytoplankton community composition remains an open question. The Antarctic Peninsula fjords offer an ideal system to understand the effect of ice-ocean forcing on phytoplankton community, providing an extreme in the spatial gradient from the glacio-marine boundary to the Western Antarctic Peninsula (WAP) continental shelf. We found that glacial meltwater input altered surface salinity and was enriched in dissolved iron and nitrate. The three major groups of phytoplankton fueled by glacial input were: cryptophytes, diatoms, and a group of unidentified small flagellates. Deep learning algorithms for predicting community abundance captured the effects of these environmental factors on the phytoplankton community. Our results show that the fjord has relatively high phytoplankton biomass combined with high macro- and trace nutrient concentrations when compared to other WAP regions. We confirm that flagellates can be the dominant taxon in Antarctic fjords and we suppose iron concentration alone is insufficient to predict diatom growth. Furthermore, marine terminating glaciers enrich the fjord with nitrate even if the main circulation is not driven by glacier meltwater discharge. As glacial meltwater continues to alter the phytoplankton taxonomic composition, it will have an important implication for higher trophic levels and add significant uncertainties to the prediction of regional ecosystem dynamics and biogeochemistry.

1464

High-resolution surface phytoplankton community composition and implications for biogeochemical cycling across the Atlantic Southern Ocean: group-specific contributions to chlorophyll-a and particulate organic carbon

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Phytoplankton community size structure and taxonomic composition play a key role in trophic carbon transfer, biogeochemical cycling, and food-web dynamics. In the Southern Ocean, high-resolution in situ measurements of phytoplankton community composition are scarce despite the expectation that climate change will drive large shifts in species distributions and ecological functioning. We used pulse-shape recording flow cytometry to evaluate live phytoplankton community composition, cell size and biovolume at high resolution (every ~40 km) across the Atlantic Southern Ocean from the subtropics to the Marginal Ice Zone (MIZ) in winter and spring 2019. In winter, pico- (<3 µm) and nanophytoplankton (3-20 µm) were 10-100 times more abundant than microphytoplankton (>20 µm). While these small phytoplankton contributed less to biovolume than microphytoplankton, their contribution to chlorophyll-a fluorescence was four-fold higher, suggesting that they were more active during this season. In spring, the abundances and chlorophyll-a contributions of small and large phytoplankton were similar, but large phytoplankton contributed more to biovolume (~70%). In winter, dinoflagellates and diatoms dominated north and south of the Polar Front, respectively, while in spring, dinoflagellate abundance was highest in the Subantarctic Zone (SAZ) and diatoms (e.g. Chaetoceros spp., Fragillariopsis) were similarly (and dominantly) abundant across the entire transect, except in the SAZ. Large diatoms were particularly abundant in the MIZ, consistent with an ice-edge bloom. Along with their implications for ecosystem functioning, high-resolution taxonomic data such as those presented here are required to ground-truth satellite measurements of ocean colour, which are used to estimate primary production at large scales.

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Enhancing E. superba conservation management by evaluating krill fishery data and its use for krill variability analysis

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Krill, Euphausia superba, are both a key component in the Southern Ocean food web and a key target of one of the largest fisheries in the Southern Ocean. In 1982 the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) was established to conserve Antarctic marine life by, amongst other things, managing the Southern Ocean fisheries. Since 1992 under CCAMLR's scheme for international scientific observation, krill fishing vessels carry a scientific observer to collect biological data from the harvests. This unique dataset can provide an insight into the spatial and temporal changes in krill variability from a new perspective. The expansion of high quality data sources and research methods is crucial for enhancing the effectiveness of current management strategies, and it is therefore important to evaluate the quality of krill fishery data and determine further uses for it. The main focus of this presentation is to evaluate data derived from fishing vessels and data derived from research vessels to determine possible gaps in collection methods. With predicted changes in environmental conditions and increased pressure from the fisheries, enhancing data quality through collection diversification is crucial for future management strategies.

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Monitoring and projecting change in the lower food web of the Southern Ocean using the SCAR Continuous Plankton Recorder survey: how can it help to prioritise and evaluate large-scale spatial protection?

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The SCAR Southern Ocean Continuous Plankton Recorder Survey (SO-CPR) has covered over 238,000 km in the Southern Ocean since 1991. We present an analysis of circumpolar zooplankton distributions in relation to satellite and oceanographic model hind-cast data over the period 1997–2019. Statistical methods based on modelling environmental suitability are used to extrapolate SO-CPR measurements in space and time. Seasonal and spatial patterns in modelled environmental suitability for 6 key groups of zooplankton are summarised. Trend analysis suggests that between 1997 and 2018 the environmental suitability for copepods (both cyclopoid and calanoid), foraminifera, and larvaceans has increased, especially in frontal regions of the Indian sector. In contrast, the environmental suitability for pteropods in some areas, particularly over the Ross Sea shelf, has significantly worsened over the last 20 years. Linearised analysis is used to explore the environmental drivers of the projected changes in zooplankton, especially in the context of changing patterns of primary productivity observed by ocean colour satellites. The patterns of change provide an observational basis to help prioritise large scale spatial protection in the Southern Ocean.

965

Following the pathway of Circumpolar Deep Water intrusions into Maxwell Bay – Antarctic Peninsula

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The western Antarctic Peninsula (WAP) have experienced the impact of global physical drivers. An increase in the westerlies have provided an increase of the inputs of circumpolar deep water (CDW) onto the continental shelf, the transport of this water mass has been linked to an increase of ocean heat and identified as a driver of marine glaciers retreat. The objective of this study is to provide observational and modeling evidence of the pathway, frequency and exchange of the CDW intrusions into a coastal embayment. The study area is Maxwell Bay located in the South Shetland Islands (SSI) Antarctic Peninsula. The pathway of intrusions of CDW was simulated using a high-resolution circulation model implemented with the Regional Ocean Modeling System (ROMS). Additionally, observations of salinity and temperature at different depths were undertaken during oceanographic campaigns during summers 2017-2020 at Maxwell Bay. The results showed that intrusions of modified CDW (mCDW) are a permanent feature in the circulation of the SSI, the intrusions were observed entering the Bransfield Strait through a gap between Smith and Snow Islands and continuing along the continental slope south of the SSI, observations from oceanographic cruises were consistent with the vertical structure and signature of the mCDW. There was no evidence of the mCDW entering Maxwell Bay. These results suggested that ocean circulation via intrusions of mCDW is not the main driver of Maxwell Bay glaciers retreat, other physical drivers like atmospheric forcing should be further explored.

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Iron requirements in Southern Ocean phytoplankton species change with light availability

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Phytoplankton blooms constitute regions of intense primary production, facilitating the sequestration of anthropogenic carbon dioxide. The Southern Ocean is considered a high-nutrient low-chlorophyll region, abundant in nitrate and silicate but often characterised by low chlorophyll concentrations due to iron limitation of phytoplankton growth. However, the Southern Ocean is also a high-latitude ocean where phytoplankton can be limited by light, particularly in winter or when cells are deeply mixed by upper ocean turbulence. Consequently, a mechanistic understanding of how phytoplankton are co-limited by iron, light and the environmental conditions that control their respective supply, is critical to better model and predict primary productivity and carbon uptake in the Southern Ocean.

We conducted a series of incubation experiments during a research cruise off East Antarctica during the Austral summer of 2019 to investigate the effects of iron and light co-limitation on phytoplankton growth. The results from the incubations confirm that iron limitation has a stronger effect under high-light conditions, but substantial spatial differences were observed in treatment responses. We employed underway and satellite data to explore the differences between stations and how the effects of iron and light co-limitation are influenced by physical properties in the area such as mixed layer depths and frontal boundaries. Here we will present a synthesis of our findings based on experiments and ancillary environmental data.

1723

Diatom-driven patterns of cobalt and vitamin B12 uptake in Antarctic Seas

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Antarctic coastal waters are limited primarily by iron and co-limited by cobalamin (vitamin B12), an essential micronutrient for most eukaryotic phytoplankton that is only produced by prokaryotes. The ecological cycling of B12 and its metal co-factor cobalt influence primary productivity also community composition, with ramifications for carbon export and biogeochemical feedbacks in the region. A thorough understanding of the cycling of cobalt and B12 is limited by the lack of in situ measurements of uptake into the marine microbial community. In this study, we conducted radiotracer incubation experiments across 15 sites to measure concurrent uptake rates of cobalt and B12 during the Cobalamin and Iron Co-Limitation of Phytoplankton Species expedition from the Amundsen Sea to Ross Sea and Terra Nova Bay, Antarctica (Dec 2017 - Feb 2018). Uptake rates integrated with nutrient, hydrographic, and pigment data, reveal that diatoms dominate the uptake of cobalt and B12, consistent with prior shipboard nutrient-amendment studies. The highest uptake rates occurred in the upper 75m in regions of fresher water masses, indicative of glacial and sea-ice melt. There is minimal cobalt uptake at depth, confirming the nutrient-like dynamics of cobalt in Antarctic waters. Lastly, the relatively high cobalt and especially B12 uptake rates suggest vitamin stress and higher cobalt stress than previously observed in this region. To date, this study is the largest collection of cobalt and B12 uptake rates from Antarctic waters and will help constrain the ecological cycles of cobalt and B12 and ground truth model development.

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Nutrient stoichiometry in zooplankton and the implications on biogeochemical cycles

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Zooplankton serve as trophic links between primary producers and higher trophic levels, and represent effective vectors for carbon export. Recent evidence suggest that zooplankton also represent an important source of regenerated nutrients fuelling phytoplankton production. Despite these emerging studies, quantifying the contribution of zooplankton to phytoplankton production proves difficult because a) zooplankton nutrient stoichiometry varies by an order of magnitude and b) biogeochemical components of global ocean models assume a fixed nutrient stoichiometry which allows for nutrients to be recycled in a predictable manner. We examined the nutrient stoichiometry (iron:phosphorus, copper:phosphorus, cadmium:phosphorus, manganese:phosphorus, nickel:phosphorus, cobalt:phosphorus and zinc:phosphorus) in zooplankton across 5 size fractions to identify the drivers of observed variability. Some nutrients (manganese, cobalt and nickel) showed no significant difference in stoichiometry between size fractions. In contrast, zinc, iron, copper and cadmium showed a significant difference in stoichiometry between size fractions. We find that nutrient stoichiometry in zooplankton reflects a combination of phytoplankton stoichiometry and physiological demand. Phytoplankton nutrient stoichiometry can span an order of magnitude and higher than seawater nutrient stoichiometry. This is especially pronounced for iron, where some phytoplankton undertake luxury iron uptake which can drive the high iron stoichiometries measured in zooplankton. Zinc and copper are required for enzymatic activities in zooplankton. Copper is further required for respiration. Consequently, zooplankton demonstrate higher zinc and copper stoichiometries relative to other nutrients. Overall, our study highlights differential nutrient uptake by zooplankton driven by diet and demand which influences model estimates of oceanic nutrient recycling.

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Regional and local drivers of Antarctic krill distribution in the South Orkney Islands region: modelling the impact of physics and behaviour

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Antarctic krill, a key species in the Southern Ocean ecosystem, is unevenly distributed around Antarctica on circumpolar, regional and local scales. Ocean currents are a key driver of their transport and distribution patterns, but behaviour also plays a major role. In this study, we focussed on the South Orkney Islands region, situated in the southwest Atlantic sector of the Southern Ocean and one of the main fishing grounds for Antarctic krill. We explored the effects of physical and behavioural drivers on krill distribution using an individual based model (IBM), incorporating key relevant behavioural traits, specifically vertical migration and association with sea ice. We used two complementary suites of model experiments. At the large scale, the IBM was forced by ocean and sea ice fields from a 1/12° ocean-sea ice model, whilst at the regional scale it was forced by output from a high-resolution (~2.5 km) regional model. The behaviour of krill under sea ice had a significant impact on distribution patterns: association with sea ice increased the probability of transport from the western Antarctic Peninsula to the South Orkney plateau, and decreased transport times. Strong regional oceanic flows had a weaker influence on transport pathways, and local recruitment and retention tended to decrease. Of particular interest for fisheries is a canyon on the northwest of the plateau where krill aggregations frequently occur. We will present first results of simulations investigating the effects of high-frequency variability in the flow field (e.g. tides) on flux into and retention in the canyon.

1600

Temporal and spatial variations of the fCO2 in the surface waters of Terra Nova Bay polynya of the Ross Sea, Antarctica

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We present the direct observations of fCO_2 in the Terra Nova Bay polynya of the Ross Sea by a long-term monitoring near the Korean Antarctic base, Jang Bogo, since February, 2015, and by survey of the fCO_2 in the surface waters of the TNB polynya onboard R/V Araon during summer season. The TNB polynya opens small area (~1000 km^2) in winter while exposing to the atmosphere in larger than 8 times of the winter polynya in summer enhancing air-sea gas exchange. The long-term monitoring indicates that the difference of fCO_2 ($DfCO_2$) between the surface seawater and overlying air varied widely from ~-200 µatm in February to ~40 µatm in early October. On the other hand, the spatial mean $DfCO_2$ by ship-borne survey gives a half of the value of the spot observations suggesting heterogeneous distribution of fCO_2 in the TNB polynya. Daily mean of air-sea CO_2 flux in the TNB polynya widely varied from ~-3 g C/m^2/d to ~0.5 g C/m^2/d. Based on these observations of fCO_2 in the TNB polynya, the annual uptake of CO_2 came up with ~30 g C/m^2, which takes into account the fraction of sea-ice concentrations estimated from AMSR2 microwave emission imagery. Extrapolating to all polynyas surrounding Antarctica, we expect the annual uptake of ~ 10 Tg C of CO_2 from the atmosphere. This is comparable to the amount of CO_2 degassed into the atmosphere south of the Antarctic Polar Front (62°S).

1429

Eddy-modified iron, light, and phytoplankton cell division rates in the simulated Southern Ocean

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We examine the effects of Southern Ocean eddies on phytoplankton cell division rates in a global, multi-year, eddy-resolving, 3-D ocean simulation of the Community Earth System Model. We first identify and track eddies in the simulation and validate their distribution and demographics against observed eddy trajectory characteristics. Next, we examine how simulated cyclones and anticyclones differentially modify iron, light, and ultimately population-specific cell division rates. We use an eddy-centric, depth-averaged framework to explicitly examine the dynamics of the phytoplankton population across the entire water column within an eddy. We find that population-averaged iron availability is elevated in anticyclones throughout the year. The dominant mechanism responsible for vertically transporting iron from depth in anticyclones is eddy-induced Ekman upwelling. During winter, in regions with deep climatological mixed layer depths, anticyclones also induce anomalously deep mixed layer depths, which further supply new iron from depth via an increased upward mixing flux. However, this additional contribution comes at the price of deteriorating light availability as biomass is distributed deeper in the water column. Therefore, even though population-averaged specific division rates are elevated in Southern Ocean anticyclones throughout most of the year, in the winter severe light stress can dominate relieved iron stress and lead to depressed division rates in some anticyclones, particularly in the deep mixing South Pacific Antarctic Circumpolar Current. The opposite is true in cyclones, which exhibit a consistently symmetric physical and biogeochemical response relative to anticyclones.

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Application of Dynamic Energy Budget (DEB) models to Antarctic case studies

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In ecological modeling, the Dynamic Energy Budget (DEB) approach concerns individual metabolism, for which food is converted to reserve, which is mobilized for maintenance, growth (of structure) and maturation or reproduction, in ways that depend on temperature.
DEB models can rely on both experimental and/or literature-mined data to quantify the age, body length and weight of the different organism's life stages, and provide information on reproduction, growth and metabolic rate according to environmental conditions. DEB models can be used in a wide range of organizational scales from the organ to the individual, population, or species levels. They also have a broad range of applications, for example in delineating the effects of (toxic) chemical compounds or global change on individuals' physiology; comparing species performances; understanding the geographic distribution of species or populations; and optimizing bio-production (aquaculture, agriculture) or support stock management and conservation decisions. To date, DEB models constitute one of the most powerful approaches to characterize metabolic performances of individuals and can be calibrated for data-poor animals. So far, DEB parameters have been estimated for more than 2,000 animal species and applications to polar case studies are growing.

In the proposed poster, the different steps of model calibration are presented through several applications and case studies. Finally, a call is launched to all Antarctic biologists who are interested and willing to apply DEB modeling to their own case studies.

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Individual-based model of population dynamics in Abatus cordatus, a sea urchin endemic to the Kerguelen Plateau, under changing environmental conditions

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The Kerguelen Islands is a sub-Antarctic archipelago of the French Southern Lands. Emerging close to shifting oceanic fronts, they are likely to be challenged by climate change, and coastal marine areas are particularly at risk. Assessing the responses of species and populations to environmental changes in such remote areas is challenging and ecological modelling can be a helpful approach to address conservation issues. In the present work, a DEB-IBM model (Dynamic Energy Budget – Individual-Based Model) was generated to simulate population dynamics for the echinoid Abatus cordatus, an endemic species of the Kerguelen Plateau characterized by dense demes in shallow, sheltered marine habitats of the Kerguelen Islands. The model relies on a DEB approach initially developed at the individual level. Then, it is upscaled to the population level for which an IBM enables to model population dynamics as a product of individual physiological responses to changing environmental conditions. The model was first calibrated for a reference site to simulate the response of a population to variations in food resources and sea water temperature. It was then projected to predict population dynamics at other sites as a response to IPCC scenarios RCP 2.6 and RCP 8.5 of climate change. Applied for the first time to a sub-Antarctic benthic and brooding species, such a dynamic model can prove useful to address conservation issues in regions where access and bio-monitoring are true challenges.

1378

Implementation of the Long Term Ecological Research network of the French Southern and Antarctic Lands (LTER ZATA " Zone Atelier Antarctique et Terres Australes"): toward an overall monitoring of the southern ecosystem through its marine and terrestrial communities

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Since 2000, the French Long Term Ecological Research network of the French Southern and Antarctic Lands (LTER ZATA " Zone Atelier Antarctique et Terres Australes") has endeavoured to monitor the dynamics of biodiversity in Antarctic and sub-Antarctic marine and terrestrial ecosystems. Our LTER encompasses multiple scientific programs and can provide access to long term monitoring of more than 40 marine, freshwater and terrestrial vertebrate species (including 27 bird species), 20 terrestrial and freshwater plant and invertebrate species. For some species, monitoring was initiated well before the 2000s, as earlier as the years 1960-1970. More recently, monitorings have been initiated at the community level for pelagic and coastal marine biota, and were complemented by eco-physiological, eco-epidemiological and stress observing projects focussing on multiple species and communities. The main objective of our LTER is to provide a general dashboard to assess health of southern ecosystems along with the selective pressures and overall resilience due to environmental changes. The French LTER ZATA has strongly benefited from sustained support from the French Polar Institute over decades, clearly linking fundings and resource allocations to our capacity to assess and understand southern ecosystems. In this talk, we will give a first picture of this dashboard based on our existing databases. We will also present future developments and strategies that, for sure, have now to be integrated at the international level.

1424

Biogenic substrates-associated macrofauna in the Antarctic benthic food web: organic matter sources and habitats for a highly diverse and abundant community

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Many organisms are capable to produce changes in the surrounding environmental conditions, generating new habitats that can be used as shelter, food, and even as reproduction sites for other organisms. In this work, we studied the diversity, composition and structure of macrofauna associated to three biogenic (algae, sponges, and hydrozoans) substrates related to main trophic levels of a community (producers, filter-feeders, and carnivores, respectively) and one non-biogenic (rocky) substrate, and we quantify the main organic matter sources of surrounding habitats (sediment, water, and meltwater) in four sites of the Antarctic peninsula during the Chilean Antarctic Scientific Expedition (ECA-54). Biogenic substrates showed that organic matter was higher in the lower trophic level (algae, 60.2%) than higher level (carnivore, 20.6%). Water (1.3%), meltwater (2.4%), and sediment (1.4%) samples showed low content of organic matter. The benthic bottom was characterized for presenting gravel as main sedimentary fraction (55.4%). A total of 19,365 organisms belonging to 22 higher taxa were collected. Amphipods (40.6%) and isopods (9.9%) were associated to producers, while gastropods (26.2%) and polychaetes (5.8%) to carnivore substrates, being the most abundant taxa across sites and substrates. Despite this, community composition showed a high overlap among biogenic substrates, while community structure showed a differentiation between producers and carnivores vs filter-feeders vs rocky (CV=51.1%) substrates. We suggest to assess the isotopic functional role of biogenic substrates to obtain a better comprehension of the relationships between substrates and associated macrofauna.
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Molluscan diversity patterns associated to biogenic substrates at the South Shetland islands, Antarctic peninsula

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Antarctic region includes more than 8,000 species of animals, which 88% belong to benthic species, and more than 50% being endemic species. Among molluscs, gastropods and bivalves are the dominant taxa with more than 890 and 380 species, respectively. Only a few studies have reported molluscan diversity relationships associated to biogenic substrates. In this study, a total of 16,750 molluscs belonging to 25 genera and 34 species associated to three biogenic and one non-biogenic substrates were collected, which were sampled in three sites at the Antarctic peninsula during austral summer of 2017. This sampling allowed to estimate quantitatively the species abundance associated to biogenic substrates to test whether molluscs confirm predictions of specific associations between community and substrate. The higher richness and abundance of molluscs were associated to algae, where stand out the gastropods Lissarca mirialis (62.9%), Laevilitorina umbilicata (15.4%), and Laevilacunaria antarctica (8.0%) as the most important components of the molluscan assemblage. Though molluscan diversity did not follow a clear distribution pattern among biogenic substrates, changes in species composition were dominated by the habitat type, independently to the local-scale variability, suggesting that substrates biological composition condition structure of these assemblages.
Funding: Instituto Antártico Chileno (INACH) project #RT_45-16 to RDS.

1531

Scratching the surface, yet grasping the big picture: a coincidental learning from a compromised research voyage in Southern Ocean

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Assessing the state and variability of Southern Ocean ecosystems is critical to conservation as much as it is of scientific importance. Multidisciplinary observations of sufficient intensity and frequency, however, are costly and difficult to maintain. Basic, still diagnostic characterization of ecosystems based on simpler measurements will be extremely useful. We present a set of surface measurements from a disturbed research voyage in Amundsen Sea that was compromised due to an unforeseen rescue mission and unfavorable sea ice conditions and subsequently resulted in a detour journey through Ross Sea back to Amundsen Sea and then off to Pine Island Bay. A suite of data including surface temperature, fluorescence, pCO_2, and limited near-surface plankton samples allowed for a description of three different regimes, each in varied status and stages in terms of dominant plankton species (Phaeocystis, diatoms, krill and others) and carbon uptake dynamics. This is corroborated by satellite imagery and biological acoustics, although the lack of data on water column structures remains a serious deficit. We hypothesize that interaction between different temperatures, length of calm periods, and water masses generated such variability. Surface observations, appropriately designed, can greatly contribute to the understanding of the ecosystem variability across regions and years. This capacity will be vastly improved by employing underway CTD, image flow cytometry, nutrient sensors and so on. There is an obvious need to fully utilize the current and future Southern Ocean surveys, and we propose a preliminary framework, with bio-regionalization taken into account, to integrate the findings from such campaigns.

1108

Biogeochemical controls on ammonium accumulation in the surface ocean during winter in the Southern Ocean south of Africa

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The production and consumption of ammonium are essential components of the upper Southern Ocean (SO) nitrogen cycle. However, the processes driving these fluxes are not well understood in the SO, especially in winter. Nutrients, community composition, size-fractionated rates of ammonium uptake, and rates of ammonia oxidation were measured in winter 2017 across the SO between South Africa and the Marginal Ice Zone (61.4°S). Ammonium concentrations, measured 4-hourly, were lower north of the Sub-Antarctic Front (SAF) (0.01-0.26 µM) compared to south of the SAF (0.19-0.70 µM), indicating that ammonium accumulates in wintertime SO surface waters, particularly in the Polar Frontal and Antarctic Zones. Ammonium uptake rates were highest near the Polar Front (PF) at 13.2 ± 0.3 nM/day and decreased steadily south of the PF to 3.0 ± 0.5 nM/day near the ice, likely due to declining sea-surface temperatures (2°C to 0°C) and light. By contrast, ammonia oxidation rates changed very little latitudinally (12.8 ± 0.5 nM/day). Nano- and picophytoplankton dominated numerically across the region, with a higher relative abundance of heterotrophic organisms corresponding to maxima in ammonium concentrations and nanophytoplankton corresponding to minima. We attribute the accumulation of ammonium during winter to sustained ammonium production by heterotrophs in autumn and winter that outweighs ammonium consumption by temperature-limited ammonia oxidizers and temperature- and light- (and possibly iron-) limited phytoplankton. High wintertime surface ammonium concentrations, and the drivers of biological ammonium cycling, may have implications for the air-sea flux of ammonia, which is important for new particle formation and atmospheric acidity.

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Distribution of dissolved iron in an East Antarctic biological hotspot

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Primary productivity in the Southern Ocean is limited by scarce concentrations of the trace metal iron, despite high concentrations of macronutrients. Inputs such as vertical mixing or spring ice melt release iron into the marine environment, stimulating productivity. These inputs vary on both spatial and seasonal scales. Once this iron has been exhausted, microorganisms rely on biological recycling to sustain nutrient levels.

In the summer of 2019, we sampled seawater for dissolved trace metals at 19 stations across the continental shelf of East Antarctica (between 63-67°S, 135-155°E), in areas with and without icebergs. Dissolved iron concentrations ranged from below detection limit (0.04 nmol/kg) in surface waters, to 0.58 nmol/kg in deeper waters. Iron was found to be supplied from two primary sources: rising circumpolar deep water and shelf sediment resuspension. Despite these inputs however, iron concentrations were observed to remain limiting throughout all water columns (Fe* = -0.78). Correspondingly, average satellite chlorophyll a concentrations (for February, over a 16 year time period) ranged from 0.8–5 mg/m^3, with highest concentrations found over the continental shelf.

Sources of iron are key to primary productivity in this region, supporting feeding grounds for Antarctic krill and thus higher trophic levels. Here, complimentary data of krill catches and whale sightings are assessed in relation to identified iron sources. By understanding the dynamics of iron cycling in this highly productive region, we can increase our ability to appropriately manage living resources and model future Southern Ocean ecosystems under changing climate conditions.

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The environmental drivers of the physiological condition of young-of-year and mature female Antarctic krill at the Western Antarctic Peninsula: Implications for krill recruitment

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Southern Ocean pelagic productivity relies on the abundance of Antarctic krill, Euphausia superba, which fluctuates on a 5-7-year cycle and is a function of recruitment and survival. Studies attempting to explain these population oscillations suggest it is an integrated response to biological, environmental and climatic factors. We sought to understand the environmental drivers of young-of-year (YOY) and mature female (MF) condition factor (CF; g/mm3) and assessed the relationship between CF and recruitment. Krill and environmental data were collected along the Western Antarctic Peninsula (WAP) during the Palmer Antarctica Long Term Ecological Research summer cruises from 1993-2008, and climate data were obtained from online databases. Data were divided between north (Adelaide to Anvers Islands) and south (south of Adelaide Island) WAP. In the north, we found negative winter Southern Annular Mode anomalies corresponded with high YOY CF, while high diatom concentrations corresponded with high MF CF. In addition, MF CF was high when day of sea ice advance was either anomalously early by ~10 days or anomalously late by ~30 days. In the south, MF CF increased with lower chlorophyll concentrations and a shallower mixed layer. Similarly, YOY CF was greater when diatom concentrations were reduced. Krill recruitment was positively related to MF CF the preceding summer, likely in response to increased reproductive output. Our findings suggest that environmental variation affects krill population dynamics by altering krill recruitment through variability in MF CF and subsequent reproductive output, and through variability in YOY CF, potentially impacting their likeliness of survival to adulthood.

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Food web modelling to explore environmental drivers, fishing and marine protected areas on the Kerguelen Plateau

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The Kerguelen Plateau in the sub-Antarctic Indian Ocean is located at the centre of temperature and salinity gradients associated with the Antarctic Circumpolar Current and influenced by the westerly winds that drive this current. Warming and intensifying winds have influenced marine species in this region, with likely consequences for food web dynamics. The Kerguelen Plateau food web supports commercial fisheries for France and Australia, however, ecosystem studies investigating the environmental drivers of the food web are relatively few. Ecopath with Ecosim is a useful food web modelling tool for bridging the gap between data and understanding food web dynamics. In this study we used Ecosim to explore the potential of fishing and environmental processes as drivers of Kerguelen Plateau food web dynamics through time and Ecospace to explore the use of marine protected areas (MPAs) in ecosystem-based management. Results from our Ecosim model did not identify fishing as a driver of biomass trends over time, however sea surface temperature (SST) and wind were highlighted as potential bottom-up influences on food web dynamics. SST and wind were related to phases of the Southern Annular Mode, a cyclic climate driver in the Southern Ocean. Our model confirmed single species results from other studies and suggested that fishing activity in the future should consider climate variables when setting catch limits. Our Ecospace model captured the spatial distribution of food web dynamics on the Kerguelen Plateau and identified important biological areas to consider for the assignment of future MPAs.

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Capturing open ocean biodiversity: eDNA could become an efficient alternative to the continuous plankton recorder

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Environmental DNA (eDNA) is emerging as a simple and objective tool to monitor biodiversity in the open ocean. Traditionally, continuous plankton recorders (CPR) have been used in the open ocean to monitor zooplankton biodiversity. Organisms were identified morphologically through microscopy, or, more recently, genetic metabarcoding. To assess whether eDNA can capture similar biodiversity and community composition as CPR, we compared small volumes eDNA samples (1 L) to morphological CPR samples (two transects) and genetic CPR samples (two transects; 1500 L filtered seawater per CPR sample) between Hobart and Macquarie Island. For genetic metabarcoding we used a cytochrome c oxidase I (COI) marker to characterize metazoan diversity, and an 18S ribosomal RNA marker to characterize overall diversity. eDNA samples were remarkably effective at detecting metazoan species using the COI marker: across two transects spanning the subtropical front eDNA samples consistently detected almost two thirds of the species detected with genetic CPR, despite the vast difference in sampled water volume and even though genetic CPR samples had up to 50 times more metazoan sequence reads than eDNA samples. There was a large overlap of detected species, and both sampling methods detecting similar drivers of community differentiation. In comparison to morphological CPR sampling, eDNA detected up to 1.6 times more species in two transects of the same area, which showed highly repeatable results for both sampling methods. With a refinement of eDNA sampling and processing methods and standardization between studies, eDNA sampling has the potential to create an unprecedented biodiversity monitoring capacity.

1402

Biological responses to change in Antarctic sea ice habitats

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The seasonal cycle of Antarctic sea ice extent represents the largest seasonal physical change on the surface of the Earth, varying between approximately 3.1 million km2 in February and 18.5 million km2 in September. This seasonality in coverage, along with a pronounced annual cycle in light, regulates biological cycles in ice-covered waters. Sea ice is predicted to decrease in extent and duration in the coming decades and this will affect the small organisms that live in the ice as well as those that live under the ice. This work presents qualitative network models for fast ice and pack ice ecosystems and examines the effects of environmental changes on the ice and its associated biota. The quality and quantity of sea ice will be influenced by warming sea temperatures and increased precipitation. We examine how sea ice variability in future will affect algae, invertebrates and fish and explore what this means for an important Antarctic habitat.

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The Role of Climate Variability on Krill Habitat: insights from the CESM Large Ensemble

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Climate change is rapidly altering the environment of the most abundant keystone species of the Southern Ocean food web, Antarctic krill (Euphausia superba). However, there remains limited understanding of how krill habitat quality will be impacted by projected changes in oceanic conditions. Moreover, the Southern Ocean is highly dynamic, displaying dramatic fluctuations on interannual to decadal timescales, complicating interpretation of observed trends. This research uses future projections from a large ensemble of the Community Earth System Model (CESM) coupled with an empirically-derived krill growth model to assess current and future krill habitat throughout the Southern Ocean. We use the large ensemble framework to explicitly make the separation between drivers of ecosystem variability and attribute variations in krill habitat to naturally varying processes versus forced trends. This allows us to quantify the the role of climate variability as a driver of fluctuations in krill habitat, putting human-driven climate change into this important context. Our results quantify the point in time when trends forced by human-driven climate change can be formally distinguished from natural variability. Overall this research builds toward providing critical scientific information for krill fishery management in the Southern Ocean. We reflect on how our findings can be incorporated into current and future management strategies.

Report on the status and trends of Southern Ocean Zooplankton based on the SCAR Southern Ocean Continuous Plankton Recorder (SO-CPR) Survey

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The Continuous Plankton Recorder (CPR) can collect surface zooplankton continuously for 450 nautical miles during a single tow at normal ship speed. It is an effective and efficient monitoring tool for detecting surface zooplankton abundances, species composition, and distribution patterns over large oceanic scales. Zooplankton are a crucial link in the Antarctic marine ecosystem and changes in the zooplankton are likely to have substantial flow on effects through the rest of the food web. The Southern Ocean CPR (SO-CPR) Survey provides the largest comprehensive and systematic Antarctic zooplankton data set, spatially and temporally, using a consistent sampling methodology ideal for the purpose of mapping the seasonal, inter-annual, long-term and spatial variation in plankton diversity, as well as to use plankton as sensitive indicators of environmental changes to monitor the health of the Southern Ocean. Since launching in 1991, much of this work has already been published in 68 CPR based research papers, chapters, atlases, and reviews. This report highlights the achievements from over nearly 30 years of SO-CPR activities, and also includes new analyses identifying trends in relation to changes in zooplankton abundance and community composition. The continuation of the current SO-CPR program, the monitoring and mapping of zooplankton, with the continued accumulation of data, will further improve our baseline information on zooplankton abundances and distributions allowing us to detect and hopefully help understand the effects climate change impacts on the ecosystem.

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The future of Antarctic krill at South Georgia: identifying limits to their physiological capacity

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The pelagic ecosystem at South Georgia is extremely productive and supports high biomass levels of Antarctic krill (Euphausia superba) on which many higher predators depend. Sea-surface temperatures around South Georgia oscillate between 0 and 5.5°C seasonally and these warmer temperatures are already beyond the upper lethal limit of Antarctic krill populations located further south. This suggests that thermal responses of Antarctic krill differ between locations. In this study, routine metabolism of South Georgia Antarctic krill was measured across two temperature ranges, 0 to 5.5°C, the natural range at South Georgia, and 5.5 to 12.5°C, an extreme range to consider physiological limits. Comparisons were made with previously published measurements on stocks from colder locations further south. Within the natural temperature range, respiration rate data from both the present and previous studies were adequately fitted by a single Arrhenius regression (Q10 of 2.6), although South Georgia krill showed an upward deviation from this regression between 0° and 2°C. Metabolic compensation (i.e. the comparative lowering of respiration rate) at the high temperatures experienced at South Georgia was not apparent, although the higher than predicted metabolic rates at low temperatures suggests acclimation to a warm water lifestyle. South Georgia krill showed no further increase in respiration rate when exposed to acute temperatures (5.5 to 12.2°C), indicating that they were already at the limit of aerobic capacity by 5.5°C. Results indicate that even small degrees of additional warming to South Georgia waters are likely to make conditions there metabolically unsustainable for Antarctic krill.

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Size Does Matter: Krill Life Cycle Drives Particulate Organic Carbon Flux off the West Antarctic Peninsula

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The rate and pattern of carbon sequestration in the world's oceans will influence the pace of future warming, yet, the drivers of carbon export to the deep ocean remain poorly understood. To understand the mechanisms that drive carbon export in the West Antarctic Peninsula (WAP), a 21-year sediment trap timeseries from the Palmer region of the WAP, is analyzed. Analysis of the sediment trap data has found that particulate organic carbon (POC) flux is dominated by a semi-decadal cyclicity. It was found that POC flux in the WAP is mechanistically linked to the 5–6-year krill life cycle, where mean body size of the krill population is the dominant driver of driver of POC flux. Years of high POC flux are positively correlated with years where the vast majority of the krill population (83.51% ± 5.82%) is comprised of old, large adults ≥ 41 mm in length, indicating they were 5–6 years of age. Years of anomalously low POC flux were positively correlated with years where recruitment of juveniles were high and less than 40.50% ± 8.80% of the krill were ≥ 41 mm in length. These findings suggest that only the largest of krill produce fecal pellets that are large enough to sink out of the upper mixed layer, contributing to carbon export to depth, whereas young juvenile krill (16–30 mm) produce small fecal pellets that are mostly retained and remineralized in the mixed layer.

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Tracing carbon sources of POM in meltwater runoff and coastal waters in Antarctica by compound specific amino acid δ13C patterns

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Under a scenario of continued glacial melting in the Antarctic Peninsula, the fluxes of particulate organic matter (POM) from land to coastal Antarctic waters are expected to change in terms of quantity and composition. Marine POM represents a protein-rich food resource for marine organisms, while terrestrial POM has very low food value. The aim of this work is to trace main carbon sources in meltwater flow from Collins Glacier to Maxwell Bay, King George Island, Antarctica applying a novel approach based on δ13C values of essential amino acids (EAAs) in suspended POM. This approach is based on the usefulness of EAAs as recorders of primary production since animals cannot synthesize EAAs de novo. To discern among different carbon sources, we applied a Principal Component Analysis (PCA) with our data combined with data from literature. Bacterial carbon sources of POM dominated in the meltwater stream that flows from Collins Glacier, runs nearby Artigas Base and discharges in nearshore waters. This signature may be related with the export of diagenetically altered carbon from land to the sea. In contrast, diatoms and other marine algae carbon sources of POM predominated in offshore stations with high marine influence, which is probably related to primary production. Our results showed very negative δ13C pool of amino acids that characterize possible end-member for Antarctic primary productivity, so, they represent relevant data for future studies based on this approach in Antarctica.

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Tidy your biological data, transform your science

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Ever since its inception, the Antarctic treaty has placed the exchange and free availability of observation at its core. This concept is gaining traction globally. A fundamental part of this concept are the FAIR principles that require that data created by machines and humans be made findable, accessible, interoperable and reusable.

All too often, data management is treated as an afterthought in the research cycle. Time spent on data management is often conceived as less time spent on science. This view is incorrect. Data are an integral part of reproducible science and without good data management, good reproducible science is not possible. Good data management will strengthen the quality of your science and actually save time by reducing the amount of data munging needed not only by your future self but also future students, collaborators and colleagues.

350 years ago the scientific paper revolutionised the way research was shared. Since then technology has changed dramatically allowing for much more direct sharing of observations, analyses and interpretations. Biological data standards such as darwincore have continued to evolve allowing a wider range of biodiversity data.

In this presentation we focus on data management of biological data from the perspective of a researcher. We provide an overview of the direct benefits to your research of data standards such as Darwincore, data repositories such as the Ocean Biogeographic Information System, and data sharing principles such as the FAIR Principles. We look at the common pitfalls and how to address them.

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the SCAR Antarctic Biodiversity Portal, current status and perspective

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The SCAR Antarctic Biodiversity portal (biodiversity.aq) is a gateway to a wide variety of Antarctic biodiversity information and tools. It finds its roots in the Census of Antarctic Marine life (2005-2010). It started as the SCAR - Marine Biodiversity Information Network (SCAR-MarBIN, scarmarbin.be) and the Register of Antarctic Marine Species (RAMS, marinespecies.org/rams/), the system has grown in scope from purely marine to include terrestrial information.
Currently the portal is supported by Belspo (Belgian Science Policy) as one of the Belgian contributions to the European Lifewatch-European Research Infrastructure Consortium (Lifewatch-ERIC). The goal of Lifewatch is to provide access to: distributed observatories/sensor networks; interoperable databases, existing (data-)networks, using accepted standards; high performance computing (HPC) and grid power, including the use of the state-of-the-art of cloud and big data paradigm technologies; software and tools for visualization, analysis and modeling.
Here we provide an overview of the most recent advances in the biodiversity.aq online ecosystem as well as an overview of future directions.
Through SCAR, Biodiversity.aq builds on an international network of experts that provide expert knowledge on taxonomy, species distribution,and ecology. It provides a strong and tested platform for sharing, integrating, discovering and analysing Antarctic biodiversity information originating from a variety of sources into a distributed system.

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Sea ice connections with Antarctic krill recruitment in the southwest Atlantic.

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Antarctic krill are a key Southern Ocean prey species and support the region's largest commercial fishery. Understanding climate change impacts on krill populations is crucial to understanding present and future change in the Southern Ocean, as well as proactively managing fisheries and ecosystem interactions.

Recruitment – the survival of larval krill over their first winter – is a strong driver of interannual krill abundance and population dynamics. It is thought that larvae depend on sea ice for overwinter survival, cause for concern as sea-ice extent is projected to decline significantly under unmitigated climate change scenarios. However, holistic projections of climate change impacts on krill remain hampered by knowledge gaps in how ice functions as an overwintering habitat, and which sea-ice characteristics contribute to good habitat quality.

Drawing from the findings of previous localized and large-scale recruitment analyses, we hypothesize that sea-ice drivers of krill recruitment are likely to be spatially nonuniform. We therefore employ a regionally structured study design to re-examine krill recruitment across the southwest Atlantic. Regionally explicit recruitment indices are developed using a novel mixture method to identify modes of recruits from KRILLBASE length frequency distributions. Estimates of sea-ice characteristics which are expected to be important for sea-ice habitat quality (concentration, thickness and ridging rate) are drawn from a coupled sea-ice ocean model (COCO) forced by observations. By analysing for spatial correlations between regionally specific recruits timeseries and sea-ice characteristics across the domain, we present a description of relationships and teleconnections throughout the southwest Atlantic sector.

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Working with the fishing industry to address key questions on Antarctic krill lipid dynamics with respect to a changing ocean.

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Lipids are the key currency in polar seas. The Southern Ocean ecosystem is largely driven by energy derived from Antarctic krill lipids. A key question is how krill lipid dynamics will be affected by warming and ocean acidification. To address this question fine scale seasonal and temporal data is required. We collaborated with a commercial krill fishing company operating in the South Atlantic region to access fine scale samples. Here we present total lipid, lipid class and fatty acids profiles of fishery-derived samples of Antarctic krill analysed every fortnight over six years. These data provide high-resolution information on the seasonality of krill lipids. Krill lipid profiles varied significantly within and between seasons. We demonstrate the dynamic seasonal relationship between specific lipid biomarkers and krill lipid classes. Additionally, we utilised remotely-sensed data (Chlorophyll a and sea surface temperature) coupled with krill lipid data to examine within and between year variation of krill biochemistry. Results from a long-term experiment are also presented on the effects of rising ocean pCO2 on krill physiology and krill lipid biochemistry. Outcomes from these combined analyses suggest that Antarctic krill are remarkably adaptable to a changing environment.

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Exploration of Patagonian toothfish-fishery-ecosystem interactions, and responses to environmental change on the Kerguelen Plateau through qualitative network modelling

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Patagonian toothfish (Dissostichus eleginoides) is an important component of the marine ecosystems around subantarctic islands, and is also a valuable fishery target species. Around Heard Island and McDonald Islands in the Indian Sector of the Southern Ocean, there was a sharp decline and subsequent strong fluctuations in fishery catch rates of this species over a short period in 2016, coinciding with a marine heatwave in the area. This suggested that changes in fish behaviour, rather than the toothfish population, were the underlying cause of the observed catch rate fluctuations, and raised questions of how toothfish and the ecosystem will respond to future environmental change, and how this may affect fishery indicators and viability into the future.

To better understand the mechanisms through which environmental changes affect toothfish and their behaviour, we constructed qualitative network models representing toothfish, the ecosystem and the fishery. These models were assembled based on expert opinions from industry, managers and scientists, draw on concurrent quantitative analyses, and are designed in a way that facilitates testing of alternative hypotheses for environmental and fisheries drivers of changes in catch rates in the region. We present results showing the likely response of this system to different scenarios of change, the mechanisms by which environmental change can propagate through the system, and how sensitive the predicted responses are to particular model components. This work will guide future monitoring programs by identifying important indicators of change, and furthers our understanding of the fishery-ecosystem-climate dynamics on the Kerguelen Plateau.

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Life stage matters when estimating the ecological functional roles of Southern Ocean pteropods

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Southern Ocean pteropods play important functional roles in biogeochemical cycling and in providing trophic links between primary producers and secondary consumers. However, compared to krill and copepods, very little effort has been made to differentiate pteropod life stages in much zooplankton-related research, which may consequently limit the wider ecological picture. I present results from our investigations into population and flux dynamics, as well as spatial pattern modelling of pteropods. Pteropods from all life stages were taken from two sediment trap experiments as well as from preserved samples, all representing three separate voyages throughout the Indian Sector. In both sediment trap experiments, highest fluxes were measured for veliger-stage Limacina helicina antarctica (<0.3 mm) relative to all pteropod species and age classes. Among a suite of variables tested, fluorescence and sinking particulate organic and inorganic carbon had the most explanatory power for the abundances of shallow water thecosome age class and species composition. Gymnosomes were largely influenced by increasing adult L. helicina antarctica counts. Egg mass abundances were primarily driven by spatial covariates, temperature, and the presence of larger pteropods. Changes to pteropod population and community dynamics in response to near-future climate change will have cascading effects throughout Antarctic epipelagic food webs, and these results provide a small-scale regional snapshot of patterns in structure from the under-surveyed region of the Southern Ocean, and demonstrates the need to incorporate all life stages to measure climate change responses as each are potentially governed by different variables.

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Estimating fecundity in the Southern Ocean thecosome pteropod, Limacina helicina antarctica, using image analysis

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The quantitative analysis of physical form and shape, or morphometrics, can be a powerful tool when applied to investigating life history strategies of organisms. When the shape and size of organisms are microscopic, challenges in morphometric analyses can be minimised with the use of image analyses software platforms. Pteropod egg masses possess hundreds, sometimes thousands, of eggs within their matrices and manually estimating counts can be time consuming and prone to error. Image analyses can effectively automate processes involved with performing egg counts and early life stage morphometric measurements and has shown to possess high levels of success compared to more traditional, manual methods. Software platforms such as ImageJ have been effectively employed in experimental work estimating the effects of future ocean acidification conditions on the brooding strategies of other marine gastropod species. There is potential to expand this application towards estimations of fecundity in thecosome pteropods, known to be sentinels of ocean acidification in the Southern Ocean. Little effort has been made to estimate fecundity in Southern Ocean pteropods based on their egg masses. Using preserved samples from three research voyages, we aimed to better understand early life history strategies in the common Southern Ocean thecosome, Limacina helicina antarctica. Using ImageJ, we developed an automated technique to count eggs within egg masses and tested the accuracy against manual counts. A linear prediction made between both methods was determined as statistically significant ($R_2 = 0.92$, $p < 0.05$), suggesting this to be a promising technique to investigate sensitive microscopic organisms.

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Fatty-acid composition of 34 species of Antarctic macroalgae across a gradient of annual mean ice cover

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The western Antarctic Peninsula supports a diverse assemblage of subtidal macroalgae, covering more than 80% of the benthos on hard substrates in depths of up to 40 m in some regions. The algal community is dominated by several large perennial brown algae but over 100 species are known on the Peninsula. Macroalgal detritus may provide key support to benthic food webs, however, the trophic links between algae and basal consumers on the Antarctic Peninsula are not well described. Algae synthesize fatty acids (FA) which are nutritionally valuable for consumers and useful as biomarkers for tracking trophic pathways in marine foodwebs. In April-May 2019, we collected a diverse assemblage of subtidal algae at 13 sites along the western Antarctic Peninsula from Anvers Island (64 deg S) to Marguerite Bay (69 deg S), spanning a gradient of annual mean ice cover from 40-90%. We analyzed the FA composition of 250 samples from 34 taxa of subtidal algae (8 Ochrophyta, 24 Rhodophyta, 1 Chlorophyta, and 1 Bacillariophyceae) across this geographical range. We compared the multivariate FA composition of a core list of seven algal taxa that we collected at multiple locations across this ice cover gradient, to test whether the FA signatures of macroalgae differ with proportion of ice cover, and used the more comprehensive list to test the similarity of FA between closely related species. As expected, we found both high order taxonomic structure to the FA signatures of macroalgae determined by phylogeny, and within-species variation associated with collection location.

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20-years of observations at the Australian Southern Ocean Time Series (SOTS) deliver an important baseline for the biological carbon pump (BCP) and its natural interannual variability

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Particle fluxes at SOTS in the Subantarctic zone (SAZ) south of Australia, ~47°S, 142°E, were collected with sediment trap moorings from 1997 – 2017, with nominal depths of 1000m, 2000m and 3800m. Annually integrated POC fluxes were close to the global median (1.2 ± 0.4 g m-2 yr-1 to 1.0 ± 0.2 g m-2 yr-1 at 1000-3800m), indicating that the SAZ exports considerable carbon to the deep sea despite high-nutrient, moderate chlorophyll characteristics. The particle composition (% w/w) was dominated by biogenic ballast minerals especially carbonates (63 - 69%) and opal (10 – 12%). POC contributed between 5 and 8%. Seasonality was moderate, with lower but non-zero fluxes in winter. Interannual variations in peak and non-peak fluxes caused the period required to collect 50% of the mass flux to vary from ~50 to 150 days (much of the global range). Nearly 80% of this flux variance is represented by strong spring and moderate late summer export episodes. This characteristic of moderate seasonality with significant interannual variations, yet relatively constant annual fluxes is likely to be useful to select appropriate models for the simulation of environmental-ecological coupling and its role in controlling the BCP. The large proportion of biogenic carbonates makes SOTS important for monitoring ocean acidification impacts on the BCP. Over the 20 yr record, no trend has yet been detected in total, PIC, or POC flux, and this will serve as an important baseline against which potential future changes in this globally significant region can be measured.

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Crustacean guide for predator studies in the Southern Ocean: A Legacy of SCAR

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Crustaceans are an important component in the diet of numerous predators of the Southern Ocean (water masses located south of the Subtropical Front). As identifying crustaceans from food samples using conventional methods is not easy, a crustacean guide was written to aid scientists working on trophic relationships within the Southern Ocean. Having the needs of the scientists in mind, we gathered information from > 100 species from 53 families of the most relevant crustaceans in the diet of subantarctic and Antarctic meso- and top predators, including information on distribution, their relevance in predator diets, sizes, availability of allometric equations and practical procedures to differentiate crustacean species within each family. Additional information of bibliography is added if families possess more that the species mentioned in this book. It is noted that a large number of species still has no allometric equations and taxonomic status of some species has to be (or remains to be) clarified. This presentation aims to describe the book that was produced within the international effort under the Scientific Committee on Antarctic Research (SCAR) programs, expert and action groups, namely SCAR AnT-ERA, SCAR AnT-ECO, SCAR EGBAMM and ICED.

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Comparative structure of Antarctic benthic communities

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Understanding the trophic interactions in the context of a food web is a fundamental requisite to elucidating ecosystem processes and functions. To explore the structure of two nearshore benthic communities we compare by Leyman's metrics the main trophic groups inhabiting Fildes Bay and South Bay (Doumer Island) in the Antarctic Peninsula. The analyses that nitrogen ranges (NR) and the horizontal breadth of the food web (CR) in South Bay were higher than Fildes Bay, revealing more diversity of prey from different trophic levels and a wide diversity of food sources assimilated by consumers. MNND and SDNND metrics indicate a smaller trophic redundancy (individuals with dissimilar trophic ecologies) and a more uneven trophic niche (uneven individual packing) in the benthic community of South Bay than the benthic community of Fildes Bay. In summary, these results indicate food-limited system in Fildes Bay in comparison with the benthic community of South Bay, which could be suggesting a reduction in habitat heterogeneity in Fildes Bay, where specialists feeding behavior are being replaced by a more generalist feeding behavior.

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The autumn dietary changes of Antarctic krill in the Antarctic Peninsula for the past half-decade.

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Antarctic krill (Euphausia superba) in the Antarctic Peninsula, the keystone species in the Southern Ocean, not only provides the energy supply for the marine predators for the summer reproduction, but also support fishery for almost all seasons. Accumulation of nutrition for overwintering has been explored a lot on this species, but little is known on the diet of krill around the Antarctic Peninsula region in autumn. In this study, we used krill samples collected from commercial fishery that sampled around the Antarctic Peninsula and in the Bransfield Strait in autumn 2015 to 2019. Biomarker fatty acid contents of individual krill were analysed to investigate the annual, regional and sexual variation in diet of krill. Both year and sex brought significant differences in most of the biomarkers. Of all variables, the factor year was the dominant one, diet of krill in autumn thus can be divided into three types, a very similar diet compositions that contributed high PUFA accumulation in 2015 and 2016, a more diversified and inclusive food sources diet in 2017 and 2018, and a concentrated diatom-indicator herbivory intake with particular higher diatom-indicator fatty acid and lower carnivory indicators of C20:1 and C22:1 levels in 2019. Using fishing vessel as the sampling platform to long-term monitor trophodynamics of krill, particularly during the poor-studied seasons and regions, can enhance the understanding on ecology of krill.

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Seasonal variation in natural growth rate of Antarctic krill (Euphausia superba) in the Antarctic Peninsula region

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Antarctic krill (Euphausia superba) is the keystone species in the Southern Ocean, however the key biological parameters, such as growth rate, are kept unclear, particularly in the poor-studied seasons. This information is limited to develop fishery management and conservation of this species. The natural growth rate of Antarctic krill is usually calculated using the instantaneous growth rate (IGR) method. So far, this work has mostly been carried out in austral spring and summer, and several related studies in winter and autumn have been based on land-based aquarium. However, significant differences in physiological implications of krill may be overlooked between land-based aquarium and natural environment. Therefore, work on growth estimation based on in-situ aquarium with simulated natural environment can provide important data to seasonal growth estimation of krill in nature. In the study we estimated the growth of krill in the Antarctic Peninsula region during different seasons (early autumn to mid-winter). Negative growth or shrinkage was obvious during this period, especially in winter (July), the lowest growth rate reached -0.10371 mm day-1. Significant differences are also occurred between seasons. The reasons that related to growth of krill, such as temperature, food quality, sea ice, area are further discussed. Our study, for the first time, estimated the seasonal growth rate of krill during autumn to winter using in-situ simulated natural environment. The results derived in this study are updated the information on growth of krill and can further be used to stock assessment model of krill population as the input variables.

SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 21

RESPONSE TO CLIMATE CHANGE: PHYSIOLOGY AND ADAPTATION OF ANTARCTIC AND SOUTHERN OCEAN LIFE - A TRIBUTE TO GUIDO DI PRISCO

Cinzia Verde

Lloyd Peck, Camila Signori, C-H. Christina Cheng

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Temperature but not carbon dioxide, stimulates growth in Southern Ocean phytoplankton

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Southern Ocean phytoplankton have been shown to overcome the low light and low iron (Fe) environment through genomic and physiological adaptations. Together, these adaptations allow the efficient use of light and Fe to photosynthesize optimally in this cold polar region. Through biological and physical processes, the Southern Ocean (SO) accounts for approximately 40% of global carbon fixation. Model projections indicate that light, temperature, Fe and CO2 (thus pH) in the Southern Ocean are likely to change simultaneously in the future due to changing climate. Although prior investigations have constrained the response of SO species to changes of individual environmental variables, multiple species responses to concurrent changes is unclear. This study adds to a growing research focus which aims to understand how marine biota will respond to climate changes over the coming century. It also aims to uncover underlying adaptations that allow SO phytoplankton to fix and export carbon in spite of cold temperatures, low light and growth limiting iron concentrations in this region. The evidence presented discusses the evolutionary ramifications for dispersal into the SO and suggests different evolutionary histories of SO diatoms isolated from the same location.

135

Climate change and chemical ecology: Determination of natural products in two species of Bryozoans, Himantozoum (Himantozoum) Antarcticum (Calvet, 1909) and Chartella Tenella (Hincks, 1887)

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The marine environment is exposed to global change and one of its effects is the increase of the water temperature, affecting all marine living species, even changing their metabolism. Many benthic organisms produce secondary metabolites (natural compounds) which are used as a defensive system against predation, competitors, microorganisms, pathogens, fouling, etc. In our study, our goal is to determine if there are variations in the natural product composition of two species of bryozoans when temperature is higher than usual. Therefore, two species of bryozoans were selected, representative of two different environments, "Himantozoum (Himantozoum) antarcticum" (Calvet, 1909) from Antarctica, and "Chartella tenella" (Hincks, 1887), from the Mediterranean Sea. The experiments consisted in keeping the animals at three different temperatures, 15ºC, 20ºC, and 25ºC for the species "C. tenella", and 0ºC, 5ºC, and 10ºC for the species "H. antarcticum". The experiments were done in filtered seawater aquaria, with a total of 40 organisms, 20 of each species for a total of two weeks for the Mediterranean samples and four weeks for the Antarctic samples. After organic extraction and clean-up of the samples, the determination of the different compounds was done using chromatography techniques coupled to ultraviolet-visible and a mass spectrometry detector (HPLC-MS). Chromatogram profiles show different composition between bryozoan extracts coming from the two environments, and samples kept at different temperatures present different chemical pattern, and therefore an effect of temperature on bryozoan natural products is observed.

1436

Microbial diversity and role in carbon cycling at the Southern Ocean Time Series (SOTS) site, sub-Antarctic zone

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The Southern Ocean plays a critical and disproportionate role in global climate regulation, buffering the impact of anthropogenic climate change. Of the world's oceans it absorbs ~40% of the CO2 and ~75% of the excess heat generated by human activities. Microbes form the majority of the biomass in the Southern Ocean and are key drivers of carbon and nutrient cycling. However, these microbial ecosystems are relatively unexplored and baseline data from which to measure how microbial diversity and function will respond to environmental change is extremely limited.

The present research focuses on the Southern Ocean Time Series (SOTS) site within the sub-Antarctic Zone (~142°E, 47°S). Time series observations from the SOTS moorings are crucial to understanding the ecosystem processes that impact carbon cycling; providing a rich, biogeochemical dataset. Microbial ecology studies of environmental samples collected from SOTS over three field seasons are combined with physicochemical observations to build, for the first time, a baseline picture of the microbial community against which future changes in ecosystem structure and function can be measured.

This talk will reveal the diversity and function of the SOTS microbial ecosystem and begin to highlight the community's role in carbon cycling. It will investigate the function of these microbial communities in carbon cycling by measuring rates of remineralisation of particulate organic carbon and changes in community structure during remineralisation. From this basis, the potential impacts of climate change on microbial carbon cycling in the Southern Ocean will be discussed.

1273

Branchial osmoregulatory response of Notothenia rossii upon temperature and salinity changes

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Antarctic fish are strictly marine and have evolved in stable thermohaline conditions. Recent climate changes have contributed to rises in water temperature and forecast models indicate the rate of such changes will increase in coastal regions of maritime Antarctica, leading to further ice melting and freshening of shallow waters in enclosed areas.

Notothenia rossii were collected in shore waters from King George Island, and acclimated from natural temperatures (0-2°C) to 4-8°C and from 32‰ to 20 and/or 10‰ by addition of freshwater to recirculating tanks, over a period of up to 10 days. Blood samples were used for osmolality and ion-contents, and gills were preserved for determination of NaK-ATPase (NKA) activity, gene expression and for histology and fluorescence immunohistochemistry (FIHC).

Reduced salinity resulted in lower osmolality and decreased NKA activity showing limited hyperosmoregulatory ability. This was accompanied by modifications in the expression of genes coding for ion-transporters (NKA, NKCC, CFTR, NHE), water channels (aquaporins) and tight junction membrane barrier proteins (claudins). FIHC shows these fish present a typical distribution of chloride cells in the gill filament, with abundant levels of NKA and NKCC in sea- and brackish water, but do not appear to efficiently upregulate NHE in brackish water. Additionally, high temperature further reduced osmolality, mainly due to reduced sodium and chloride, increasing the osmotic gradient between extracellular fluid and seawater and resulting in up-regulated branchial NKA activity, thus contributing to the energetic demands.

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914

Antarctic sponges and climate change: are they winners rather than losers?

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Research assessing the effects of warming on Antarctic species have shown that the limited capacity of many Antarctic organisms to cope with climate change. Experimental studies at individual/molecular levels have demonstrated that some Antarctic species are sensitive to even small changes in water, also having significant effects at the community level. Antarctic sponges are important members of Antarctic benthic communities, being dominant in abundance and playing important functional roles. Based on previous knowledge on Antarctic organisms along with evidence from studies on sponges from other latitudes, it has been thought that sponges have a very limited or no capacity to cope with warming. Studies conducted on Antarctic sponges around Doumer Island, Palmer Archipelago (western Antarctic Peninsula) provide new insights about the potential resilience of some sponges to warming scenario and other climate change stressors, suggesting that not all Antarctic sponges might be "losers" as previously thought. Results show that sponges have some capacity to cope with small increases in temperature, showing genomic complements and hosting highly stable bacterial communities (in terms of community structure and predicted functional patterns) despite being exposed to abnormal seawater temperatures (3°C) and high rates of temperature increase (0.15°C day-1). Previous research has reported a considerable plasticity in seasonal and metabolic plasticity in Antarctic sponges, which along with the potential role of their symbionts providing capacity to sponge hosts to cope with rapid environmental change, suggest they may improve the chances of more sponge species to become winners under the climate change scenario.

525

Survival in the Southern Ocean with Little or No Antifreeze Proteins

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Antifreeze glycoprotein (AFGP) is long regarded as an adaptive evolutionary innovation that crucially enabled the Antarctic notothenioids to colonize and diversify in the freezing Southern Ocean. Lacking this adaptive trait would seem paradoxical and incompatible with life for these endemic fish. However, two nototheniid species appear to be exceptions – Lepidonotothen squamifrons and Pleuragramma antarcticus (Antarctic silverfish). We investigated the biochemical and molecular bases of this peculiar trait alteration. L. squamifrons completely lacks active AFGPs in its blood. P. antarcticus has minimal circulating concentrations of AFGPs (~1mg/mL) versus its highly fortified (upwards of 30mg/mL) relatives. We sequenced the genome of these two species to isolate and characterize the AFGP loci for potential genotypic changes or defects. L. squamifrons has drastically reduced AFGP genotype, but some coding sequences (cds) appear intact. Tests for AFGP mRNA expression showed transcriptional silence likely caused the absence of the active protein. In contrast, P. antarcticus genome appears to contain large numbers of AFGP cds. However, closer scrutiny reveals much of them are non-functional SSR-like fragments scattered throughout the genome. The canonical AFGP family and its actual coding capacity will be clear when high quality assembly of the silverfish genome is complete. How does L. squamifrons survive without any AFGPs? In field and in lab tests suggest that L. squamifrons seek non-freezing bottom water layer to avoid freeing. It may serve as an adaptive model for notothenioid survival in a warming sea.

1596

Effects of benzophenone-3 on temperate and polar microalgae under future warming scenarios

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Benzophenone-3 (BP-3) is an organic ultraviolet (UV) filter which is commonly found in various sunscreen products as a type of UV protectant. With the increased awareness of skin cancer, the usage of sunscreens had increased dramatically. The amount of BP-3 that was found in water bodies raised concerns on the effects of this chemical towards aquatic organisms. Moreover, the impact of global warming is becoming more apparent in recent years. In this study, a total of four microalgae from polar (Chlorella UMACC 400 and Chlorella UMACC 401) and temperate (Chlorella pyrenoidosa and Chlamydomonas reinhardtii) regions were used to investigate the interactive effects of BP-3 (0, 100, 200, 300, 400 mg/L) and temperatures (ambient, ambient + 4℃, ambient + 8℃) for 72 hours. The cell size, specific growth rate (μ), photosynthetic pigments (chlorophyll-a, chlorophyll-b, carotenoids) and biochemical composition (carbohydrate, protein, lipid) were measured to assess the impacts of BP-3 on microalgae under future warming scenarios. The results showed that high concentration of BP-3 (200, 300 and 400 mg/L) affected growth, photosynthetic pigments and biomass of microalgae. However, the two temperate microalgae exposed to 100 and 200 mg/L of BP-3 at 26℃ (ambient + 8℃) resulted in increased in photosynthetic pigments and biomass. However, this was not observed in the polar microalgae. Further investigation is required to understand mechanisms used by these microalgae to cope with multiple stressors.

874

Long-term trend in reproductive cycle underpins inter-annual variation in the gametogenic development of an Antarctic marine invertebrate

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Reproductive success is an important measure of fitness, determining an animal's resilience to change and predicting population continuity and survival. Patterns in reproductive cycles and their drivers remain challenging to interpret since it is often the interplay between multiple factors that is responsible for regulating reproductive performance. This study investigates the long-term reproductive ecology of an abundant Antarctic sea urchin, Sterechinus neumayeri, by characterising the seasonal and inter-annual variability observed, and the key patterns that underpin reproductive allocation. The reproductive cycle of S. neumayeri was investigated over a seven-year period (2012- 2018) using monthly measurements of investment in gonad tissue and observations of gametogenic development. Seasonal and inter-annual variation in reproductive condition were also explored in relation to the changing environment. Our analyses identified significant annual increases in gonad index over the length of the time series. This suggests a long-term signal that varies on a decadal-scale which may underpin the seasonal and annual variability observed in reproduction. We hypothesise this trend is driven by the interplay between local and regional environmental factors. However, both gonad index and oocyte size co-varied with small changes in seawater temperature, which fluctuated by less than 2°C. These findings suggest that temperature plays a critical role in regulating reproductive performance in Antarctic marine invertebrates. In addition, this study underscores the need for future research that utilises long-term biological time series to better describe and reliably predict faunal responses to climate change, especially in terms of variability and consequences for reproductive performance.

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Consequences of marine heat waves on the energetics and functioning of Antarctic marine invertebrates

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Extreme climate events, such as marine heat waves (MHW), are forecasted to escalate in many areas of the climate system under future global change scenarios. However, the implications of MHWs on the biological patterns and processes of marine organisms are relatively understudied in comparison to the effects of gradual temperature shifts. The difficultly of studying MHWs results from their unpredictable nature and past infrequency, where most studies to date have focused on the effect of gradual climatic trends. This study investigates how MHWs affect biological functioning in the Antarctic marine environment using a functionally important and abundant invertebrate, the sea urchin, Sterechinus neumayeri. Animals collected directly from the field were exposed to three rates of warming, 1 day/°C, 2 days/°C and 3 days/°C, until their thermal maximum temperature was reached. During warming, basic functioning, including ability to feed, food absorption efficiency, righting ability and metabolic rate were monitored. Initial findings suggest that despite thermal maximum temperatures occurring at > 9°C above ambient, functioning began to deteriorate when temperatures were increased by only a couple of degrees above ambient in all treatments. Our results show that although this species appears robust to warming in terms of lethal limits, it is in fact still highly sensitive, in terms of basic functioning, to just small changes in temperature, which will ultimately affect long-term survival of the species. This study highlights the need to consider the sub-lethal effects of short-term warming as incidences of MHWs continue to increase across the globe.

1114

A chicken-and-egg dilemma: hemoglobin-and-red blood cells in white-blooded icefishes?

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Antarctic icefishes fascinate physiologists and evolutionary biologists because of their unique white blood lacking hemoglobin. The presence of mature erythrocytes in the icefish blood has, however, been controversial. Thus a chicken-and-egg dilemma still remains: Which came first? The loss of the capacity to make mature erythrocytes or the loss of hemoglobin genes?

To address this conundrum, we questioned the initiation of erythropoiesis in icefishes and characterized the morphology of erythropoietic cells in notothenioid peripheral blood.

Histological analyses of head kidney sections identified a few immature erythropoietic progenitors (proerythroblasts) in icefish, indicating that icefishes hematopoietic marrow still initiate an erythropoietic program, although attenuated. Morphological analysis of erythropoietic cells in blood smears from 13 red-blooded notothenioid and nine icefish species revealed that icefish proerythroblasts were morphologically undistinguishable from those of their red-blooded relatives. The most advanced erythropoietic cells observed in icefish blood were morphologically similar to, but smaller than, maturing erythroblasts in red-blooded species. Together, results suggest that erythropoiesis in icefish arrests at an intermediate stage of erythrocyte maturation. The peripheral blood of dragonfishes, the sister lineage to icefishes, contained mature, but circular, erythrocytes. Genomic analyses of published notothenioid genomes revealed potentially deleterious mutations in erythrocyte membrane skeletal genes, mimicking human spherocytosis and elliptocytosis conditions.

Our analysis therefore suggests either that the most recent common ancestor of icefishes and dragonfishes possessed abnormally shaped erythrocytes or that relaxed selection on components of the cytoskeleton independently led to alterations in erythrocyte shape and formation in dragonfishes and in icefishes.

981

Deciphering the molecular mechanisms at play in the acclimation of the Antarctic sea urchin Sterechinus neumayeri to futur climate change scenario

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Global warming is threatening marine Antarctic fauna, which has evolved in isolation in a cold environment for millions years. Facing increasing temperatures, marine Antarctic invertebrates can either tolerate or develop adaptations to these changes. Adaptation in Antarctic ectotherms will require at least hundreds of years. On a shorter time scale, their survival and resistance capacity to warming will be driven by the efficiency of their phenotypic plasticity. Successful acclimation to higher temperature has been shown possible in a limited number of marine Antarctic invertebrates. This acclimation to future climate change scenarios is mainly studied using the Ctmax method, which links animal physiology and thermal ecology. Although powerful to determine whether these taxa could successfully acclimate to out of range temperatures, traditional methods do not disentangle all the underlying biological, physiological and sub-cellular mechanisms at play. The aim of this study was to unravel the molecular mechanisms underpinning acclimation to different ocean warming scenarios in the Antarctic sea urchin Sterechinus neumayeri and to determine whether it is capable to adjust for maintenance of homeostasis under warming conditions. A combination of genomic, physiological and behavioral-based approach was used on individuals acclimated to three experimental temperatures: control (ambient temperature in summer, ca. 1°C), control +2°C and control+4°C, corresponding to warming predictions by the end of the century. Altogether our results showed an important regulative effort after acclimation to ocean warming with notably adjustments of major energy sinks processes (e.g. proteins and RNA synthesis).

823

Global paleoclimate change and the loss of erythrocytes by Antarctic icefishes

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Understanding adaptation to environmental change is of fundamental importance to predicting the evolvability of species in the Anthropocene. Antarctic icefishes (Channichthyidae) lost the ability to produce red blood cells as the Southern Ocean (SO) cooled and dissolved oxygen concentrations rose, providing a test case for analyzing the evolutionary genomic responses to environmental change and the potential for species resilience as the SO now warms. By integrating paleoclimate records with an extensive phylogenomic dataset, we demonstrate relaxation of purifying selection across erythrocyte-associated genetic regions following a rapid decline in global temperatures and the formation of stable ice sheets. Acceleration of variation in erythrocyte-associated regions continues in modern Antarctic notothenioids, including red-blooded species. For example, we detected predicted deleterious variation in the beta-spectrin gene of red-blooded dragonfishes, one of which has spherocytic erythrocytes like those observed in humans with mutations in this gene. Despite loss-of-function mutations in a few key erythrocyte-specific genes, we show that most of the erythroid genetic toolkit has been maintained in icefishes. Interestingly, there is a bias in the accumulation of drift in putative gene-regulatory regions flanking genes expressed late in erythropoiesis. Together, results indicate that erythropoiesis in icefishes is blocked late in erythrocyte differentiation, consistent with the presence of proerythroblasts in icefishes. Our results provide a comprehensive phylogenomic perspective of the genetic changes in icefishes that led to loss of erythrocytes and a framework for understanding the potential for their adaptive resilience as the SO warms.
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Climate change induced shifts in sea ice algae nutrient content: Species, community and trophic implications.

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The polar regions are experiencing a reduction in sea ice extent, yet the biological ramifications of these changes remain largely unexplored. Understanding the implications on sea ice algae is particularly important, as they provide up to 26% of total primary production in seasonally ice-covered waters and up to 50% in perennially ice covered waters. As sea ice algae are limited by a range of environmental factors, including water temperature, salinity and light availability, the ongoing environmental changes in the polar regions will shape the algal community composition, phenology and macromolecular composition. Combined, these effects alter the nutrients supplied to higher trophic levels and even small changes at the production level can have large cascading effects on higher trophic organisms in the short polar food webs. This study traces the changes in community composition and individual physiologies of sea ice algae as a result of environmental change. Specifically, we use FTIR microspectroscopy to perform single-cell analyses to investigate how sea ice algae shift in carbon partitioning between the macromolecular storage of proteins, lipids and carbohydrates in response to natural variation in temperature, salinity and light. This phenotypic plasticity exists to satisfy physiological requirements, such as increasing lipid accumulation in response to increases in salinity, in order to facilitate osmoregulation. However, this plasticity on a broad scale alters the nutrient availability to higher trophic levels, affecting modifications in nutrient transfer through the polar marine systems. Through tracing these changes, this study improves our understanding of the biological ramifications of sea ice decline.

1606

The stress axis and response to acute stressors in Notothenia rossii acclimated at different temperatures

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Antarctic fish evolved in a stenothermal environment, subject to very small fluctuations in temperature throughout their life (–1°C - 2°C). Their ability to respond to increased temperature is uncertain. We aimed at evaluating the mechanism and capabilities of the HPI axis in Antarctic fish in three sets of experiments. Four groups were placed at 2ºC. Upon a standard stress test (SST: chasing+netting +1min air exposure) fish were returned to tank and sampled after 1,4,24h. Six groups were acclimated to 2,5,8ºC for 10-days. At this point the control group of each temperature was sacrificed. The other group received SST and sacrificed 90-min after. Plasma and tissue samples were collected for cortisol and stress-related genes and the interrenal used in-vitro to determine sensitivity to ACTH. Eight groups at 2ºC were injected with drugs involved in blockage or stimulation of cortisol release/action (saline, cortisol, dexamethasone, metyrapone, spironolactone, mifepristone) and then kept at control or transferred to 6ºC and sampled after 36 hours. After SST cortisol peaks between 1-4 hours and reduces to basal between 24-48 hours. Temperature influenced the cortisol response to SST. At higher temperatures cortisol levels in non-stressed group are as high as in fish subjected to SST. Interrenal sensitivity at high temperature showed little response to ACTH, suggesting low sensitivity and/or exhaustion. Manipulation of the HPI-axis showed these fish to respond in a way similar to what has been reported in other fish families in temperate or tropical environments.
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Microbial diversity and community structure across space and depth in Gerlache Strait (Western Antarctic Peninsula)

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The Gerlache Strait presents several environmental changes from natural fluctuations and anthropogenic impacts, such as glacier melting/retreat, lowering of the seasonal ice-sheet and one of the fastest rates of temperature increase. As microorganisms play a vital role in the element cycling in the pelagic system, this study aimed to analyze the taxonomic composition, diversity and community structure of Bacteria and Archaea of the Gerlache Strait, besides infering their functionality and understanding the impacts of environmental factors in these communities. A total of 38 samples were collected from the euphotic zone to deep waters during the austral summers of 2013, 2014 and 2015. The region V4 of the 16S rRNA gene was sequenced using the Illumina platform and bioinformatics tools were used for data analysis. The observed OTUs varied from 306 to 631, and bacterial taxa (90.4%) prevailed over archaea (9.6%). These microorganisms were clustered according to depth (categories below or above 100 m) and temperature (below or above 0°C). An increase in the archaeal diversity, mainly Marine Group II and Nitrosopumilus, was observed with depth. Regarding bacteria, there was a higher relative abundance of Deltaproteobacteria and Cyanobacteria at lower temperatures. The relative abundance of Gammaproteobacteria and Deltaproteobacteria was higher below 100 m deep, while for Alphaproteobacteria, Oxyphotobacteria e Bacteroidia were relatively more abundant in the euphotic zone. Since temperature is a key driver of microbial communities in the maritime Antarctica, climate-driven change will possibly shift the microbial community structure disturbing biogeochemical cycles, especially the sulfur and nitrogen.

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Assimilation and turnover rates of specific lipid compounds in dominant Antarctic copepods: CSIA, a cutting-edge tool to reveal ecophysiological adaptations in polar oceans during times of climate change

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The study revealed species- and stage-specific differences in lipid accumulation of the dominant Antarctic copepods, the primarily herbivorous Calanoides acutus (copepodids CV, females) and the more omnivorous Calanus propinquus (females), storing wax esters and triacylglycerols, respectively. Feeding carbon-labelled diatoms to these copepods, 13C signatures elucidated assimilation and turnover rates of total lipids as well as specific fatty acids and alcohols. The 13C incorporation was monitored by compound-specific stable isotope analysis (CSIA). CV stages of C. acutus exhibited an intense total lipid turnover and 55% of total lipids were labelled after nine days of feeding. In contrast, total lipid assimilation of female C. acutus and C. propinquus was clearly lower with 29% and 32%, respectively. The major dietary fatty acids 16:0, 16:1(n-7) and 20:5(n-3) showed high turnover rates in all specimens. In C. acutus CV copepodids, the high rates of the de novo synthesized long-chain monounsaturated fatty acids and alcohols 20:1(n-9) and 22:1(n-11) indicate intense lipid deposition, whereas these rates were low in the females. These high-resolution data of lipid assimilation and turnover provide a much better understanding of lipid metabolic pathways. Lipid accumulation of zooplankton key species, especially herbivores, is a crucial process in polar oceans buffering the extreme seasonality of primary production. These life history traits are well synchronized with seasonal events. However, environmental change at high latitudes may decouple e.g. light- and temperature-controlled processes and thus result in a mismatch situation of primary and secondary production impacting lipid biosynthesis of herbivores.

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Potential disruption of gelatinous zooplankton to subantarctic ecosystem function caused by climate change

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Due to the formation of intermediate and mode waters in the subantarctic Southern Ocean, the region is considered to be an important deep ocean carbon sink. Common zooplankton in this area such as krill and copepods play a noteworthy role in the downward carbon flux, for example by producing carcasses. In autumn 2019, a bloom of the pelagic tunicate Pyrosoma atlanticum was observed in the subantarctic Southern Ocean, far from its normal subtropical home. Pyrosome bloom frequencies are thought to increase under marine heatwave conditions, which may lead to increasing numbers in the subantarctic Southern Ocean as the warm East Australian Current extends further south. During this study, pyrosomes exceeded the biomass of other common zooplankton, so we investigated their potential contribution to downward carbon transport and compared the results to krill. We measured bacterial remineralisation of pyrosome and krill carcasses. Further, we analysed their sinking velocity in a settling column and estimated the transport to the deep Southern Ocean. Due to their high biomass and abundance in the water column, pyrosome carcasses were a hotspot for bacterial activity. Additionally, the fast sinking speed and relatively high carbon content indicate their importance in the subantarctic carbon flux. We will finish this talk by exploring the possible impacts of increasing pyrosome abundance could have on the subantarctic ecosystem biodiversity and overall function.

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Shifts in ascidian distributions in response to rapid glacial retreat in Marian Cove, King George Island, WAP

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Impacts of tidewater glacier retreat on epibenthic megafauna were investigated in Marian Cove, a small tributary embayment of KGI where tidewater glaciers have retreated about 2 km over the last six decades and ~45% of its bottom turned into ice-free area. The benthic communities were investigated from almost entire water depths (10-90 m) at four selected sites with varying distances from the glaciers using a remotely operated vehicle (ROV). Analysis showed that filter feeders, particularly ascidians were the most diverse (14 out of 63 taxa captured in the ROV images) and the most abundant (~128 inds./m^2) taxa, contributing most (~64%) to the differences of the total epibenthic assemblages, suggesting a utility of ascidians as a sentinel taxon for assessing climate impacts. Furthermore, the ascidian distributions were well differentiated by the distance from the glacier front and also with water depths. The two opportunistic species Molgula pedunculata and Cnemidocarpa verrucosa predominated (>90% of density) at all depth close to the glaciers, while more diverse taxa (14) occurred at 50-90 m in the remote site (3.5 km from the glacier), indicating a shift in habitat stability. Sediment analysis supported the idea that ascidian shifts were primarily related to habitat stability. Given the fact that the distance was proportional with the time elapsed after the retreat, the ascidian shifts seemingly reflected successional processes over the long-term period in the past, which in turn would be expected to project future changes.

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Manganese co-limitation of phytoplankton in the Southern Ocean

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The Southern Ocean (SO) plays a critical role in global biogeochemical cycles and climate. The SO is the largest High Nutrient Low Chlorophyll (HNLC) area, where phytoplankton growth is thought to be limited mainly by iron (Fe) concentrations. But, other trace metals, such as manganese (Mn) potentially co-limit phytoplankton growth in HNLC areas. Mn is an essential micronutrient due to its roles in photosynthesis and in the scavenging of reactive oxygen species. However, its biogeochemistry remains poorly constrained.

A recent voyage following the SR3 transect, between Tasmania and Antarctica, measured incredibly low Mn concentrations over most of the section, including the lowest Mn concentrations ever measured in the SO. This suggests that SO phytoplankton communities may have a low requirement for Mn or that Mn limitation is pervasive. In subsequent voyages to the Southern Ocean Time Series (SOTS) site, located in Subantarctic waters, south of Australia, we performed Fe and Mn addition incubations on natural phytoplankton communities during austral spring and autumn.

Results showed different seasonal responses of the phytoplankton communities to Fe and Mn additions. In spring, only the addition of both Fe and Mn resulted in significant biomass increase, suggesting Fe-Mn co-limitation. This result was not observed in autumn. Flow cytometry, along with carbon and Fe uptake measurements provided additional information on the communities involved and the physiological effect of Fe-Mn co-limitation. Overall, our findings provide physiological insights on how these Subantarctic phytoplankton communities cope with changes in natural conditions.

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Functional diversity reveals novel insights into the distribution of Southern Ocean squid

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Squids play an important role in the Southern Ocean ecosystem, as their prevalence in the diet of many top predators and their voracious feeding nature potentially exerting a top-down control on their prey species. These species are documented for circumpolar distribution and show higher numbers of squid species relation to various fronts of the Antarctic circumpolar current, presumably driven by regional oceanographic conditions. However, such knowledge is mainly built on species richness and associated occurrence-based measures, and yet information about their diversity taking into account species traits appears to be the most necessary. Here, we provided comparisons of a biodiversity distribution measure based on richness with metrics that incorporate species functional traits. We used squid occurrence data from the SCAR Biogeographic Atlas of the Southern Ocean and Global Biodiversity Information Facility (GBIF), and calculated functional diversity indices that summarize community diversity with respect to four traits, encompassing body size, feeding ecology, maximum living depth, and phylogeny. The richness of functional groups closely resembled the pattern in species density. In contrast, functional diversity of the squids showed markedly different patterns to the species density and functional group richness. Both maximum living depth and phylogeny contributed most to the pattern of functional diversity. In addition to previous “hotspot” regions, new hotspots of squid diversity were predicted for areas along the Subantarctic Zone and Antarctica. These findings imply a more complicated distribution of the Southern Ocean squid, possibly contrasting with well-known latitudinal gradients in richness.

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The role of viruses in marine polar environments and their response to change

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Viruses are the most abundant life form on earth with an estimated total abundance in the oceans of ~1030. They are responsible for 10-30% of bacterial mortality, known to control harmful algal blooms and can reduce photosynthesis by up to 78%.
In Prydz Bay, eastern Antarctica, their abundance at all depths was closely correlated with both chlorophylla and bacterial abundance. Metagenomic analyses of surface seawater from the Scotia Ridge and Prydz Bay, identified bacteriophages of the Caudovirales, especially the Podoviridae, as the most abundant. Microalgal viruses belonging to the Phycodnaviridae family, which contains most microalgal viruses, especially Phaeocystis viruses, were also identified.

Sea ice algae communities comprises a globally significant photosynthetic biofilm. While their microalgal and bacterial constituents are well characterized, there is very little information on their associated viral communities or on the virus-bacteria and virus-algae interactions within them. While high levels of interaction might be expected because of the high density of cells, infection rates, particularly of microalgae, have been found to be low. It remains unclear whether this is a result of environment characteristics, developed resistance or because of the small number of studies.
We are investigating how ocean acidification and other climate change forcings will change infection rates in ice edge blooms and sea ice ecosystems.

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Effect of ocean acidification and temperature on physiology and energetics of Antarctic krill

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Antarctic krill (Euphausia superba) is a key species in the Southern Ocean, forming an important link between primary producers and higher-level predators. A commercial fishery for krill has existed for almost 50 years, due to their high biomass and swarming behaviour, and because of its commercial and ecological importance krill are one of the best studied crustacean species. During the last several years, general concepts of krill biology and life history have changed considerably as more information is collected from the field and laboratory experiments; however, there are still only a handful of published studies examining the effects of ocean acidification (OA) on krill. Until now, there have been no long-term experiments focusing on krill and their physiological and energetic responses to OA combined with increased temperature. There is currently a gap in the knowledge as to whether krill can adapt to the changes occurring in their ecosystem, and, if they can, if a "tipping point" will arise at which adaptation can not occur. Through laboratory-based experimentation, krill physiological responses were monitored over 1.5 years. These responses included growth, reproductive maturity, metabolic activity and lipid storage. Understanding the effects of increased exposure to CO_2 and temperature on the physiological responses of krill will allow Southern Ocean fisheries management, led by the Commission for the Conservation of Antarctic Marine Living Resources, to parameterise existing Southern Ocean ecosystem models and continue fishing for the species in a sustainable manner.

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Responses from sub-Antarctic phytoplankton communities to short-term trace metal incubations in early austral spring and links with the biogeochemical signature of sea ice

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Phytoplankton (PL) growth in the Southern Ocean (SO) buffers the effects of rising atmospheric CO2 and is thought to be limited by micronutrients (e.g. Iron). Formation of winter sea-ice is thought to store trace metals (TM) which are released in spring and summer, providing PL with necessary micronutrients for growth. During the SCALE 2019 expedition in the Atlantic sector of the Southern Ocean we assessed if PL growth is limited by TM during early austral spring in the sub-Antarctic and marginal sea ice region. The influence of “non-limiting” nutrients (e.g. Al) was also investigated as recent studies suggested that Al may have beneficial growth effects on PL 1,2,3. Ice cores from the marginal ice zone indeed show higher concentrations of TM and Chl-a compared to in situ waters. The phytoplankton community response to addition of TM compared to control in short-term incubations was evaluated from chl-a concentration, flow cytometry, and phytoplankton photo-physiology. Results suggest that phytoplankton communities may not have been limited by TM at the time of sampling. Further, Al only additions had a negative effect on PL community structure. It is possible that the early melts of sea-ice from the marginal ice zone are a potential source of trace metals beyond their threshold limiting concentrations.

1 Zhou et al. (2018) doi: 10.1016/j.jinorgbio.2017.09.022
2 Liu et al. (2018) doi: 10.1016/j.marpolbul.2018.02.011
3 Zhou et al. (2018) doi: 10.1007/s10533-018-0458-6

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Antarctic krill microbiota and its relationship with climate change through a metagenomic approach

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Antarctic krill is one of the most abundant organisms on the planet and lives only in the Antarctic region, it is the main food of many organisms and is the basis of the food chain in Antarctica, it feeds mainly on phytoplankton but can feed on other organisms as well as waste or decomposing organic matter. Its diet is very versatile and it is known that it has a great metabolic capacity mediated by microorganisms, these microorganisms have adapted to the conditions of the host as well as the physical or environmental environment being an important source of genes and bioactive compounds for the industry. This study aims to identify the main microbial patterns that make up the microbiota of the Antarctic krill through a metagenomic approach aimed at 16S RNAr genes and establish what are the relationships established with the main oceanographic variables such as sea temperature, dissolved oxygen, salinity and pH, as an instrument for assessing the effects of climate change in the area between the Bransfield Strait, Joinville and surrounding Elephant Island in the Antarctic Peninsula. Finally, it should be noted that this study is part of the ANTAR XXVI and XXVII scientific expeditions developed by the Peruvian state during the southern summer 2019-2020.

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Evaluating the effects of ocean warming and freshening on the physiology and transcriptomic response of the Antarctic limpet Nacella concinna

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Antarctic coasts are highly vulnerable environments where temperature have remained very constant for millions of years. These unique environmental conditions have generated a large number of stenoic species that could be highly sensitive to future projections of climate change. We investigated the effects of increasing seawater temperature and decreasing salinity on the physiological and transcriptomic performance of the subtidal Antarctic limpet Nacella concinna, collected at Fildes Bay, King George Island. Adult limpets were exposed to an orthogonal combination of five temperatures (1, 4, 8, 11, 14 °C) and two salinities (20, 30) for a 60-day period. A drastic increment in mortality was observed with seawater warming and 100 % mortality was recorded in limpets exposed to 14, 11 and 8 ºC, both salinities. At 4°C, sub-lethal effects were observed with a negative scope for growth associated with a mild up-regulation of genes involved in oxidative stress (e.g. glutathion peroxydase). At 1°C (control), a positive scope for growth was observed in both salinities and no mortality was recorded. However, an important regulation of limpets transcritpome was observed with an up-regulation of stress-related proteins (chaperons) and a down-regulation of genes involved in carbohydrate and ATP metabolism. Scope for growth was negatively affected by the interaction of ocean warming and freshening which inhibited the expression of chaperons (HSP). The stenothermal character of N. concinna demonstrate the limited ability to cope with the most severe models of global warming and freshening projected for the Antarctic and Magellan regions by the end of the century.

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The hypoxia response in Nothothenia coriiceps

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We sought to determine if the evolution of Antarctic notothenioid fishes in a cold, oxygen-rich environment has diminished their capacity to mount a robust molecular response to hypoxia. Notothenia coriiceps were held at normoxia (10 mg L -1 O_2) or hypoxia (2 mg L-1 O_2) for 12 hours. Protein levels of the master transcriptional regulator of oxygen homeostasis, hypoxia- inducible factor-1α (HIF-1α), were quantified in nuclei of heart ventricles using western blotting. Changes in gene expression in heart ventricles, as well as in brain, liver, and gill, were quantified using RNA-Seq. Although protein levels of HIF-1α increased in heart ventricles in response to hypoxia, the expression of only 22 genes increased, none of which are known to be regulated by HIF-1α. Liver displayed the largest molecular response to hypoxia with the expression of 664 genes significantly changing, including an upregulation of genes in the MAP kinase and FoxO pathways, and ones involved in glycolytic metabolism and vascular remodeling, indicative of a canonical molecular response to hypoxia. Overall, the molecular response to hypoxia appears diminished in some tissues, but not absent, in Antarctic notothenioid fishes.

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Impacts of ocean acidification on key members of shallow water Antarctic communities

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Macroalgae form dense undersea forests on hard bottoms along the northern portion of the western Antarctic Peninsula (WAP). Macroalgae support huge densities of amphipods which are the most numerous animals in the forest communities. Prior work from our group has shown that some species of amphipods will be impacted more by ocean acidification than others. However, the results demonstrated that longer term studies were needed on multiple members of the macroalgal-associated amphipod assemblage to understand which species may be relative ‘winners’ and ‘losers’ in future oceans. We performed a 60+ day long experiment with amphipod assemblages from macroalgae at several sites near Palmer Station on southwest Anvers Island. Amphipods and their associated host macroalgae were held under ambient, near-future, and more distant-future pH levels. The amphipods were at the same density per unit biomass of their hosts as they had been in nature. Relative winners and losers were identified at the end of the experiment. These data will inform a follow-on experiment comparing ‘winners’ and ‘losers’ to understand what amphipod characteristics are likely to contribute to relative fitness in the future Southern Ocean along the WAP.

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Are Antarctic mollusks prepared for an invasion of shell-crushing predators?

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In marine environments where shell-crushing predators are very scarce, such as in coastal zones of the Antarctic, shelled species should have thinner and less complex shells, given low selection pressure for thicker shells or harder material. This study assessed natural variation in the shell strength and the vulnerability of the dominant Antarctic limpet Nacella concinna to a novel shell-crushing predator. Limpets from the intertidal and subtidal rocky shores of King George Island (Antarctica) were collected and the breaking strength of their shells determined using an electronic tension/compression device. Shells from intertidal limpets had 66% greater breaking strength than subtidal ones, presumably due to higher mechanical forces experienced there. Limpets from the subtidal environment were also transported to southern Chile where they were exposed to a shell-crushing predator, the southern king crab (Lithodes santolla). 83% of the limpets were consumed within 24 h, the crabs broke the shell without apparent difficulty. When limpets were exposed to water-born cues of the crab for a 8-month period, there was no change in shell strength. Despite abundant evidence of shell plasticity in mollusks, our results demonstrate that this species does not modify shell mechanical properties in response to the presence of crushing predators, at least, not as a rapid response. This key Antarctic species thus appears extremely vulnerable to bioinvasions of shell-crushing predators, and further efforts to estimate the vulnerability of this and other species are needed to predict the magnitude of possible changes in Antarctic marine communities.
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Evolution of globin genes in red-blooded and white-blooded Antarctic notothenioid fish

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As Antarctic waters chilled, notothenioid ancestors adapted to cold, oxygen-rich waters followed by the evolution of icefish, which lack functional hemoglobin genes. Some icefishes also fail to express cardiac myoglobin, but all appear to retain other globin genes: cytoglobin-1, cytoglobin-2, globin-x, and neuroglobin. Functions of the corresponding proteins, however, remain poorly understood, but may include oxygen storage and protection against oxidative stress. To test the hypothesis that these minor globins evolved features related to cold hyper-oxygenated water and hemoglobin loss, we performed phylogenomic analyses, addressed evolutionary selective pressures, and followed gene expression patterns in both temperate and Antarctic notothenioids, including icefishes. Genomic analyses identified conserved syntenies, gene sequences, and protein domains for all four genes. Evolutionary analyses revealed sequence divergence between temperate and Antarctic species, suggesting evolution associated with cold adaptation. Cytoglobin-1, Cytoglobin-2, and Globin-x showed additional residue changes in icefishes, suggesting sequence evolution related to hemoglobin loss. Finally, expression analyses showed that all four globin gene expression patterns evolved with cold adaptation, and that cytoglobin-1 and cytoglobin-2 displayed additional changes in expression patterns in white-blooded Antarctic fish. We conclude that these four globins evolved as fish adapted to chilling waters, potentially providing additional protection from oxidative stress. Globin expression patterns also evolved, as cytoglobin expression increased in white-blooded fish compared to red-blooded Antarctic fish, which might provide icefishes with supplemental oxygen storage capacities. Together, these findings suggest that evolutionary modifications in globins may have contributed to the success of Antarctic notothenioid fish.

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Temperature response of active microbiome from perennial cave ice

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Icy habitats investigations unraveled the impact of climate changes on the glacier melting leading to microbiome exposure to higher temperatures when changing habitats. Our survey provides pioneering data on the heat-shock response of ice-contained microbial communities focused on their structural and functional diversity.

Shotgun metatranscriptomic analysis of the 900 years-old ice microbiome from Scarisoara cave (Romania) submitted to a three-day 4-25°C heat-shock cycling treatment followed by incubation at 4°C up to 14 days constituted the first characterization of the active microbial community from ice habitats. Both rRNA and mRNA data revealed a major variation of the microbial composition immediately after heat-shock, suggesting a dissimilar resilience of ice microbial taxa and functional response at gene transcription level after glacier melting. Among the dominating bacterial representatives, Firmicutes, Actinobacteria and Chlorobi were mostly affected, while Archaea, scarcely present in this habitat, showed a 9-fold decline of relative abundance after heat shock cycles. Fungal community appeared to be the most disturbed by the thermal shock, mainly Basidiomycota and Ascomycota taxa, while Blastocladiomycota and Chytridiomycota phyla were more adapted to temperature variations. Microeukaryotes mostly represented by heterotrophic flagellates showed a high recovery potential after heat-shock exposure. The functional response implied an upregulation of the genes coding for chaperones, polymerase sigma factor, enzymes of the TCA cycle, and implied in carbon and nitrogen regulation and cellular motility.

This first report on the presence of an active microbiome in perennial ice accumulated in caves contributes to understanding changing environments and their ecological impact due to ice melting.

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Not dead, just dormant: Building a physiological basis to understand susceptibility of an Antarctic copepod to climate change

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The calanoid copepod, Boeckella poppei, is broadly distributed in Antarctic maritime lakes that are undergoing rapid structural alterations due to climate change. This copepod species occupies the highest trophic level of these lakes, and produces embryos capable of remaining dormant for centuries when conditions are inhospitable for active life-stages. However, little is known about the biology of dormancy in B. poppei. Understanding the mechanisms responsible for the dormant stage is necessary to predict the effects of climate change on Antarctic freshwater zooplankton. This study is the first to examine dormancy mechanisms and post-dormancy development in B. poppei. Pre-emergent development in B. poppei was characterized after exit from the dormant state using morphological features visible by light microscopy. The number of nuclei increases during pre-emergent development as yolk platelets are depleted. This indicates that yolk stores must be conserved during dormancy. If yolk must be preserved, then the embryos must downregulate metabolism while dormant. It is known that intracellular acidification in brine shrimp embryos downregulates metabolism during anoxia-induced dormancy. A similar acidification is expected in embryos of B. poppei because embryos in lake sediments are likely to encounter anoxic conditions. To test this, intracellular pH during resurrection from dormancy was monitored with ^{31}P-NMR. Intracellular pH alkalinizes during post-dormancy development, indicating that pH is acidic during dormancy. In summary, embryos of B. poppei must downregulate metabolism while overwintering, and this appears to be achieved using intracellular acidification.

1254

Coccolithophore response to environmental variability in the subantarctic zone and their role in the carbonate pump: lessons from the SONaR-CO2 project

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Coccolithophores are an important component of the present and past Southern Ocean biogeochemical cycles, however their contribution to calcite production and export and their response to ongoing environmental change are largely unknown. The Marie Curie Action SONaR-CO2 aims to shed light on these issues by analysing the coccolithophore assemblages preserved in unique water column time-series collections and sediment samples from the Australian and New Zealand sectors of the Subantarctic Zone. We found that peak relative abundances of heavier Emiliania huxleyi coccoliths occurred at times of maximum annual TCO_2 concentrations in all the time series analysed. These results challenge the view that ocean acidification will necessarily lead to a replacement of heavily-calcified coccolithophores by lightly-calcified ones in subpolar ecosystems. Secondly, we estimated that coccolithophores account for about half of the annual carbonate export to the deep sea in the Subantarctic Zone. Notably, although E. huxleyi numerically dominates the assemblages, less abundant but larger species account for a greater contribution to the $CaCO_3$ flux. Combination of our results with previous studies suggests that future southward migration of oceanic fronts will result in increasing $CaCO_3$ export but, eventually, ongoing ocean acidification will overwhelm those changes. Lastly, comparison of coccolith morphometric parameters of modern (sediment traps) and pre-industrial (surface sediments) E. huxleyi assemblages revealed important differences between them. Although the signal preserved in the sedimentary record is partially obscured by carbonate dissolution, our results indicate that pre-industrial Holocene E. huxleyi assemblages were more calcified than present populations.

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Antarctic intertidal macroalgae under increased temperatures induced by Climate Change: would they thrive?

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The Antarctic Peninsula is one of the regions to be most affected by increase in sea surface temperatures (SSTs) mediated by Climate Change. Temperature is one of the most important factors mediating diversity and distribution of macroalgae, although there is still no consensus as to the likely effects of higher SSTs, especially for polar seaweeds. Some available information suggests that potential strategies to withstand future increases in SSTs will be founded upon the glutathione-ascorbate cycle and the induction of chaperone-functioning heat shock proteins (HSPs). The intertidal green, red and brown macroalgae species Monostroma hariotii, Pyropia endiviifolia and Adenocystis utricularis, respectively, from King George Island, Antarctic Peninsula, were exposed to 2 °C and 8 °C for up to 5 days (d). Photosynthetic activity (αETR and ETRmax, and EkETR), photoinhibition (Fv/Fm) and photoprotection processes (αNPQ, NPQmax, and EkNPQ) provided no evidence of negative ecophysiological effects. There were moderate increases in H2O2 and lipid peroxidation with temperature, accompanied by stable levels of total glutathione and ascorbate, with mostly higher levels of reduced ascorbate and glutathione than oxidized forms in all species. Transcripts of P. endiviifolia indicated a general upregulation of antioxidant enzymes and HSPs under warmer temperature, although with different levels of activation with time. This investigation suggested that Antarctic intertidal macroalgae may be able to withstand future rise in SSTs, perhaps slightly altering their latitudinal distribution and/or range of thermal tolerance, by exhibiting robust glutathione-ascorbate production and recycling, as well as the induction of antioxidant enzymatic machinery and the syntheses of HSPs.

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Ecophysiological and whole transcriptome responses of the rare Antarctic aquatic moss Drepanocladus longifolius to increased temperatures projected for Climate Change

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Drepanocladus longifolius is a rare aquatic bipolar moss, recently described in the Antarctica. In King George Island, Antarctic Peninsula, D. longifolius grows in inner lakes below 5 meters depth under daily and seasonally extremely changing environmental conditions, as those related with light and temperature. To address the molecular basis behind stress response and potential adaptation to future conditions of Climate Change, D. longifolius was sampled from Kitiesh lake and exposed under laboratory conditions to increasing temperatures from 2°C (control) to 8°C for 3 days at 140 µmol m-2s-1 photosynthetic activity radiation (PAR), day/night cycle of 20/4 hours. In ecophysiological response, D. longifolius does no suffer consequences in terms of photosynthetic activity, manifested in in vivo fluorescence of chlorophyll a parameters (Fv/Fm, ETR, NPQ). A de novo whole transcriptome study, sequencing with Illumina NovaSeq platform 6000, demonstrated the regulation of almost 1,400 genes, of which 626 were downregulated and 764 were over-expressed under 8°C. From the latter, there were related to primary metabolism processes such as carbohydrate metabolism, lipid metabolism, several transcription factors, seed dormancy and maintenance, and stress response associated with light harvesting complex-related proteins, enzymes involved in cell wall reorganization, dehydration and senescence response proteins, and several antioxidant enzymes and heat shock proteins (HSPs). The information suggested that an efficient tolerance response based on the activation of several increased-temperature mechanisms will provide D. longifolius efficient ecophysiological and metabolic defenses to counteract increased temperatures expected for the end of the XXI Century, even under the most negative predicted scenarios.

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Increased temperatures predicted for Climate Change induce general transcriptomic tolerance responses in the Antarctic intertidal brown macroalga Adenocystis utricularis

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Adenocystis utricularis is an ecologically relevant intertidal brown macroalga distributed from the temperate west coast of South America until the Antarctic Peninsula. In the latter, it survives under extreme environmental conditions, which compromise strong desiccation, wave action, and drastic fluctuations in radiation and temperature. In this investigation, A. utricularis from King George Island, Antarctic Peninsula, was exposed to 2°C (control) and 8°C for 3 days and 20/4 day/night cycle at 140 µmol m-2s-1 photosynthetic activity radiation (PAR). In ecophysiological response, A. utricularis is not subject to affection in photosynthetic activity, measured in terms of in vivo fluorescence of chlorophyll a (Fv/Fm, ETR, NPQ). RNA was extracted and whole transcriptome was studied by RNA-seq using an Illumina NovaSeq 6000 platform. Results demonstrated the regulation of over 640 genes, of which 151 were over-expressed and 496 down-regulated. Represented processes were related to DNA replication, repair and reorganization, fucoxanthin-chlorophyll binding proteins, transcript maturation and translation related proteins. Conversely, repressed genes were associated with ribosomal proteins, ABC transporters, aminoacids metabolism, translation, cytoskeleton reorganization, oxidative stress-related proteins and heat shock proteins (HSPs) together with other chaperones. Considering the general shut down in gene expression occurred upon an increased in temperature exposure, ecophysiological and transcriptomic results suggest that higher temperatures would be beneficial for this Antarctic macroalga´s fitness under future predicted negative scenarios of Climate Change.

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Coordination between water flow and photosynthesis in the Antarctic vascular plants in response to increased temperature

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The photosynthetic performance of Antarctic vascular species is strongly determined by their xerophytic anatomical traits. Both, Deschampsia antarctica and Colobanthus quitensis have thick and dense mesophylls, determining remarkably low values of CO_2 mesophyll conductance (gm). When these species grow at temperatures close to their optimum for photosynthesis (≈15 °C), gm increases whilst leaf density (LD) and leaf mass area (LMA) decrease. Since CO_2 and water partially share the diffusion pathways inside leaves, we hypothesized that the leaf anatomical modifications experienced by the Antarctic species in response to warmer temperature, increases their hydraulic conductivity. We evaluated the effect of growth temperature (5, 8 and 15 °C) on several anatomical and hydraulic parameters, as well as their co-variation with photosynthetic performance. At higher temperature, Antarctic plants increased their leaf hydraulic conductivity (Kleaf), and the whole plant conductivity (gplant). Increases in Kleaf and gplant correlated with decreases in LD and LMA, and with increases in the anatomical hydraulic diameter due to changes in the number and size vessels. The increase in Kleaf with temperature correlated with higher stomatal conductance and gm. Therefore, increases in water and CO_2 flows favored carbon assimilation, resulting in a coordination between the hydraulic properties and photosynthesis in response to temperature. This information is essential to make realistic predictions of the Antarctic plants response to climate change.

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Antarctic marine microbiome across space and depth

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It is expected that marine microbes, which are the main drivers of biogeochemical cycles and essential to the food web, will be affected in different ways by changing climate and oceanographic conditions in the western and eastern Antarctic Peninsula. The main goal of this research was to determine the taxonomic composition, diversity and distribution of the microbial communities across different regions and depths of the Southern Ocean. We selected samples from the epi-, meso- and bathypelagic zones of the Gerlache and Bransfield Straits, the areas influenced by the Bellingshausen Sea and the Weddell Sea, north of the Antarctic Peninsula, besides areas near the sea ice edge. By using the Illumina sequencing-based profiling of bacterial and archaeal 16S rRNA genes, 1529 OTUs were identified from a total of 74 samples. In general, the bacterial classes Gammaproteobacteria, Alphaproteobacteria, Flavobacteriia and Cyanobacteria, and the archaeal Marine Group II and Nitrosopumilus corresponded to 90% of the total taxa identified. The sea ice edge and the Weddell Sea presented the most distinctive microbial communities when compared to the other sampling areas. The microbial composition in the meso- and bathypelagic zones was very similar, with high percentages of Oceanospirillales, SAR11, SAR324, Thaumarchaeota and Euryarchaeota. Significant differences in microbial communities were obtained between sampling areas and pelagic zones. This research provides invaluable advances in understanding the spatial dynamics of Bacteria and Archaea in the water column of underexplored areas around the Antarctic Peninsula.

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How new scenario of climate change are affecting the Antarctic fish Harpagifer Antarcticus

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The climate change is modifying the Antarctic area, being the teleosts very sensitive to temperature and freshening. In addition, this temperature increase is changing the oxygen concentration, boosting the probability of fishes facing hypoxia events. These climates changes are affecting important physiological process for teleost fish as energy yielding processes, osmoregulation, oxygen consumption, immune responses and survival. The last 5 years we did experiments with Harpagifer antarcticus (Notothenioid), an Antarctic species called the spiny plunderfish. The aim of these studies was to evaluate the physiological responses according to variables of climate change, such as freshening, high temperature and hypoxia. Our results demonstrate that H. antarcticus has a CTMax at 18°C. The osmotic, stress and metabolic responses are modified by high temperature, freshening and hypoxia. The immune system (using LPS and POLY:C to stimulate the response) is being modified by high temperature. In addition, that dependence of thermal regimens H. antarcticus are chancing the prey-item from Gondogeneia antarctica to Cheirimedon femoratus.
These studies provides information relevant for understanding how the climate change is affecting the physiological and immune response of this Antarctic Notothenioid fish. This work was financed by Fondap-Ideal Grant Nº15150003, Fondecyt 1160877, VIDCA-UACH and INACH.

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Interactive effects of exposure to metals and elevated temperatures under a warming climate on an Antarctic marine ostracod

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While concentrations of contaminants in Antarctic marine waters are typically low, a number of nearshore sites, such as those adjacent to past waste disposal tips at research stations have increased levels of contaminants, including the metals cadmium, copper, lead, and zinc. To assess the risk associated with mobilisation of these metals in meltwater streams into the marine environment, chronic toxicity of metals to a common Antarctic ostracod (Bradleya antarctica) were examined. Tests were conducted at 0°C; representative of current environmental conditions. For copper, two elevated temperatures were also tested (2 and 4°C) to assess potential interactive effects of exposure under elevated temperatures. Ostracods were exposed to metals for 10 weeks, with periodic observations of behaviour and survival throughout the testing period. Sub-lethal behavioural responses were observed in the first week of exposure; however, there was no significant mortality observed up to 10 days. Toxicity increased with exposure time, up to 10 weeks, with 50% Lethal Concentrations (LC50) for these long exposures comparable to those reported for related temperate species over shorter exposures of only 10 days. The response of Antarctic ostracods to metals was therefore delayed, and may in part be attributed to reduced metabolic rate that is characteristic of Antarctic marine invertebrates living at constant low temperatures. Sensitivity to copper increased in tests conducted at the higher temperatures of 2 and 4°C, indicating that, under a warming climate, these Antarctic biota may be subject to elevated risk if exposed to contaminants.

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Ocean Acidification Impacts Primary and Bacterial Production in Antarctic Coastal Waters during Austral Summer

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Polar waters are at increased risk of ocean acidification (OA) due to the higher solubility of CO_2 in colder waters. Three experiments examining the influence of OA on primary and bacterial production were conducted during summer at Davis Station, Antarctica (68°35' S, 77°58' E). For each experiment, six 650 L tanks were simultaneously filled with 200 µm filtered coastal seawater and incubated for 10 to 12 days, with CO_2 concentrations ranging from pre-industrial to post-2100. Primary and bacterial production rates were determined using $NaH^{14}CO_3$ and ^{14}C-Leucine, respectively. For all experiments across the summer season, maximum photosynthetic rates (mg C mg chl a-^{1} h-^{1}) decreased with enhanced CO_2, reducing rates of gross primary production (mg C L-^{1} h-^{1}). Rates of bacterial production (µg C L-^{1} h-^{1}) and growth (d-^{1}) were faster under enhanced CO_2 from Days 0-4, but became more similar between treatments thereafter. Conversely, rates of bacterial cell-specific productivity (µg C cell-^{1} h-^{1}) decreased with enhanced CO_2 suggesting some cell impairment. Initial increases in bacterial production and growth with OA were enabled through reduced grazing pressure associated with fewer heterotrophic nanoflagellates. This emphasises the importance of community-based studies to best elucidate OA effects. Reductions in primary and cell-specific bacterial productivity with enhanced CO_2 occurred at concentrations greater than 2X present day (> 780 ppm) indicating resilience in the system. Decreased primary production under OA conditions may exacerbate global warming through reduced CO_2 uptake via the biological pump, and reduce food availability to higher trophic levels in the Antarctic food web.

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Fatty acid content of the Antarctic krill Euphausia superba of the Southern Ocean revealed changes under water temperature regimes

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Climate change is as a major threat to biodiversity loss, causing great alterations in marine ecosystems in the Southern Ocean. Antarctic krill Euphausia superba is a key species in Antarctic trophic food web presenting a high abundance and a crucial role at the trophic food web. Due to the scarce information in literature about the adaption of species to global warming and environmental change, it becomes crucial to determine and assess the biochemical profile of these species to a better knowledge in the trophic food web. Fatty acid (FA) are molecules with physiological roles and revealed to be good bioindicators of environmental change. In this study FA profile of E. superba collected in different sites (cold, warm and transitional waters) across the Antarctic Polar Front was determined to: 1) assess potential changes with water temperature; 2) assess the body condition of the organisms, 3) characterize the diet, and 4) compare the FA profile of E. superba with E. triacantha. Results highlight E. triacantha is more tolerant to warm than cold waters with higher abundance and diversity in FA content in warmer waters. Moreover, E. superba presents a more sensitive behavior to the sampling sites than E. triacantha. Although different food preferences, carnivorous zooplankton is one of the food sources in the diet of both species. This study highlights that under environmental change scenarios, E. triacantha have more potential to cope better in the future, and possibly having a more relevant role in the Antarctic trophic food webs than E. superba

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Show us your beaks and we tell you what you eat: Different ecology in sympatric Antarctic benthic octopods under a climate change context

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Sympatry can lead to higher competition under climate change and other environmental pressures, particularly in South Georgia region, where the two most common octopod species, Adelieledone polymorpha and Pareledone turqueti, occur side by side. As both species' beaks are commonly found in predator's stomachs and its ecology is still poorly known due to their elusive behaviour, we studied their feeding ecology through a multidisciplinary approach combining stable isotope signatures (13C and 15N), total mercury (T-Hg) analysis and biomaterials' engineering techniques (Scanning Electron Microscopy, X-Ray Diffraction, micro-Computerized Tomography and Nanoindentation Test). An isotopic niche overlap of 95.6% was recorded for the juvenile stages of both octopod species, dropping to 19.2% in adult stages. Both species inhabit benthic ecosystems around South Georgia throughout their life cycles (13C: −19.21 ± 1.87‰, mean ± SD for both species) but explore partially different trophic niches during adult stages (15N: 7.01 ± 0.40‰, in A. polymorpha, and 7.84 ± 0.65‰, in P. turqueti) (Matias et al. 2019 Mar. Environ. Res.). The beaks of A. polymorpha are less dense and significantly less stiff than P. turqueti beaks. The T-Hg concentrations in the flesh of P. turqueti where higher relative to A. polymorpha (0.434 ± 0.128 g·g-1 and 0.322 ± 0.088 g·g-1, respectively). Overall, both octopod species exhibit similar habitats but partially different trophic niches, related to different morphology/function of the beaks. Moreover, both species presented T-Hg concentrations similar to the ones found in northern hemisphere octopod species and may increase under the present climate change context.

SCAR 2020

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SESSION 22

THE ROLE OF FISH IN THE SOUTHERN OCEAN

Mark Belchier
Jilda Caccavo

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Modelling dispersal of Antarctic toothfish eggs and larvae in the Ross and Amundsen Seas – The impact of sea-ice, ocean currents and larval behaviour

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Antarctic toothfish in the Ross Sea spawn near seamounts, at depths of 1000-2000m during winter (July-August). The buoyant eggs float to the surface where they encounter near complete cover of sea-ice. They likely hatch after 40 days and juveniles are found after 2-3 years at the continental slope of Antarctica, typically thousands of kilometres from spawning locations. It remains unclear how the larvae travel from the spawning grounds to the continental slope, and how this process is influenced by the timing of the spawning, sea-ice motion, ocean currents, eddies, and larval behaviour. In this study we investigate the individual contributions of these factors distributions of toothfish larvae, using hydrodynamical data from a high-resolution ocean model hindcasts. The resolution of this model hindcast (1/15°) is fine enough to resolve mesoscale eddies in this region and model representation of the Ross Sea gyre circulation is realistic. Based on the scenario modelling, we find that a combination of all factors is necessary for larvae to reach the shelf within 2-3 years. We will also discuss interannual variability in transport routes and how these may be impacted by climate change and potentially affect recruitment in the future.

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Transport pathways structuring life history distributions of Antarctic toothfish

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In the Ross Sea, juvenile Antarctic toothfish are found in deep basins along the inner continental shelf, the result of isostatic depression by the continental ice sheet. The basins connect to the continental slope via glacial troughs exposed during ice sheet recession. Predictable transport along each trough offers opportunities for biophysical interactions with life history. Equatorward flow of dense, cold Low Salinity Shelf Water (LSSW) from the Glomar Challenger Basin mixes with inflowing modified Circumpolar Deep Water, eventually contributing to the formation of Low Salinity Antarctic Bottom Water. Deep outflow from the trough mouth sinks down the slope to join a western boundary current northward to the Iselin Bank. High Salinity Shelf Water (HSSW) flows from the Joides Basin along the Joides Trough, and down the slope into the Adare Basin. Further west, more saline HSSW forms gravity cascades down the slope from the Drygalski Trough. Two transport pathways connect northward from the Ross Sea slope to the Pacific-Antarctic Ridge where Antarctic toothfish spawn: an eastern one from the Iselin Bank, and a western one that turns cyclonically along the flank of the Southeast Indian Ridge. We compare the shelf basins and transport pathways connecting habitats currently used by toothfish over their life history. We consider which inshore basins are likely most important in contributing to adult spawning aggregations; how transport pathways from each may be expected to influence distributions along the Pacific-Antarctic Ridge; and how these biophysical interactions can be expected to change over the glacial cycle.

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Marine Ecosystem Assessment for the Southern Ocean (MEASO): Productivity and change in fish and squid in the Southern Ocean

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The Marine Ecosystem Assessment for the Southern Ocean (MEASO) aims to provide a forward-looking assessment of present and future ecological trends in the Southern Ocean ecosystems, as well as to identify gaps to address in research and management. The fish and squid MEASO chapter collates a synthesis of current knowledge, impact of drivers (past, present, and future), and prognoses. Focus is brought on major taxonomic and functional groups particularly relevant to ecosystem functioning, with case study-species illustrating impacts of important drivers on the ecosystems (e.g. fisheries, climate change). Data collection methods on fish and squid in the Southern Ocean are discussed (e.g. fisheries, scientific surveys) with respect to their inherent biases. Variations in fish and squid distributions and adaptations over glacial scales are examined, as well as impacts from more recent anthropogenic drivers (e.g. climate change, fisheries, pollution). Based on a synthesis of historical data and current knowledge, we developed a set of prognoses for fish and squid connectivity, distributions and biomasses throughout the Southern Ocean over the next 10 - 20 years and beyond. In this presentation we will describe the major conclusions regarding fish and squid emerging from this assessment, including the need to consider the synergistic impacts of concurrent drivers, as well as inter-population and inter-species variability across regions in regard to their response to drivers of change.

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Combined risk and quantitative assessment approach to Southern Ocean fisheries bycatch: Deep water skates (Bathyraja spp.) in the Patagonian toothfish fishery as a case study.

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Impact assessments on bycatch species require a basic suite of life history parameters including information on age, growth and recruitment. However for many species in the Southern Ocean these parameters are not available. Due to their deep water demersal existence little is known about skates (Bathyraja spp.) caught in the Heard and McDonald Island (HIMI) Patagonian Toothfish (Dissostichus eleginoides) fishery. By combining multiple sources of data on Bathyraja eatonii, B. irrasa and B. murrayi we aim develop a best practice framework for establishing input parameters used in population projection models. We estimated age, growth and recruitment through an integrated analysis of species morphometric, reproductive, mark-recapture and ageing data collected between 1990 and 2019 during Random Stratified Trawl Surveys and commercial fishing operations on the Kerguelen Plateau. Where input parameters could not be determined we followed a qualitative stepwise approach to obtain quantitative estimates from other species based on taxonomic, ecological and life history similarities. In the face of uncertainty a precautionary risk based approach was implemented by selecting for more conservative parameters. Input parameters were then applied to a Generalised Yield Model (GYM) to produce a simulated projection to determine the probability of stock depletion. Furthermore, we tested multiple scenarios of fishing gear selectivity within the GYM to obtain a range of future population predictions. This study provides the first estimates of long term annual yield for individual skate species in the HIMI fishery and a framework for setting bycatch limits in other areas of the CCAMLR region.

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The impacts of climate change and krill fishing on Antarctic larval fishes

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The Western Antarctic Peninsula (WAP) is one of the fastest warming regions on Earth. In addition, there was a dramatic reduction in sea ice and retreat of marine-terminating glaciers during the late 20th century. Although the increase in temperature and decline in sea ice has reversed since the year ~2000, primarily due to natural variability and Antarctic ozone recovery, under high anthropogenic emission scenarios the WAP is expected to experience prolonged warming in the future. It is critically important to understand how rapid climate change effects the WAP ecosystem. Previous work indicates phytoplankton, zooplankton, and penguins are all significantly influenced by climatic variability. However, there is less information pertaining to the influence on the unique ichthyofauna of the region, especially during their early life stages. Larval fishes in the Northern Antarctic Peninsula region are also incidentally captured by krill fishing vessels, although little is known on the scope of this bycatch due to difficulties in identifying larval fishes. This project utilizes a 27-year, continuously running time series of larval fishes collected by the Palmer Antarctica Long-Term Ecological Research (PAL LTER) Program to model the environmental drivers of ichthyoplankton population dynamics. Fishes from the PAL LTER and Australian Antarctic Division collections are also used to develop a novel identification guide for scientific observers on krill fishing vessels. Model results and observer reports are immediately necessary to assess anthropogenic influences on larval fish mortality, manage krill fishing efforts, and assist in the development of marine protected areas in the Southern Ocean.

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Fishing for DNA to study predator prey interactions of Southern Ocean fish

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The use of DNA as a dietary tracer is becoming increasingly common and has great potential to improve our knowledge of trophic interactions in a broad range of ecosystems. This talk will focus on two DNA-based diet studies that refine our view of the ecological role of fish in the Southern Ocean. Both studies used high-throughput DNA sequencing of DNA barcode markers. In the first study we characterised stomach contents of four myctophid and one bathylagid fish species collected on the southern Kerguelen Plateau. The presence of DNA from coelenterates and other gelatinous prey in the stomach contents of all five species, which are largely missed with morphological analysis, suggests the importance of these taxa in the diet of Southern Ocean mesopelagic fish has been underestimated to date. In the second study we examined the fish DNA present in the scats of Adélie penguins at Signy Island (South Orkney Islands) during the breeding season over two years. Scat DNA showed an increased diversity of fish in the penguin diet compared to parallel data collected at the colony through conventional stomach flushing. Based on these two case studies the strengths and limitations of the genetic approach to studying diet will be discussed.

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Species connectivity - Hybridization potential between notothenioid species

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Interspecific hybridization or its prevention may have contributed to the diversification of notothenioid fishes, but data supporting these hypotheses is scarce. With many related species displaying parapatric distributions, and with Antarctic and sub-Antarctic regions rapidly warming, the potential for hybridization may be greater than previously hypothesized.

To understand hybridization possibilities and investigate reproductive isolating mechanisms among notothenioids, we performed in vitro fertilization experiments between two Nototheniinae species (a female Notothenia coriiceps and a male Notothenia rossii) and between two icefishes (a female Chaenocephalus aceratus and a male Chionodraco rastrospinosus).

Embryos from the interspecies Notothenia cross initially developed but none survived past the establishment of the embryonic axis at 21 days post fertilization. The sequencing of nuclear genes from this cross identified only maternal DNA in all of the tested offspring, suggesting that the obtained cross was gynogenetic and that the N.rossii sperm activated the eggs but did not fertilize them.

In contrast, embryos from the interspecific icefish cross successfully developed and hatched into active larvae. The sequencing of nuclear genes confirmed that the larvae were true hybrids, demonstrating gamete compatibility and viability of resulting embryos. Due to logistic constraints, long-term hybrid viability, fertility, fitness, or hybrid dysgenesis could not be tested. Analysis of fishing records and literature, however, suggests that some hybridization barriers between icefishes or between other notothenioid parapatric species may be behavioral.

These results confirm previous observations of hybrids in the wild and suggest that some notothenioids species may be able to hybridize if appropriate conditions are met.

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Fisheries acoustics to study keystone species in the pelagic ecosystem of the Ross Sea region marine protected area

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On 1 December 2017, the world's largest Marine Protected Area (MPA) was established in the Ross Sea region of the Southern Ocean. At over 1.55 million km2 in size, tracking change and evaluating the value of the Ross Sea MPA is a highly complex, technical, and unprecedented scientific challenge. A first step is to improve our understanding of the key components of the Ross Sea ecosystem, and how these respond to pressures, including climate change and human activities. The open-ocean pelagic ecosystem of the Ross Sea is dominated by micronekton. Micronekton play a key role linking primary and tertiary consumers, and are thought to be a keystone group within the Ross Sea. Despite their importance, our knowledge of micronekton is still very limited. As part of the MPA research monitoring programme, research and fishing vessels have been used to collect active acoustic data in the Ross Sea region that can be used to monitor micronekton distribution and abundance. Dedicated research surveys have provided biological samples using midwater trawls to describe the community composition and ground-truth acoustic data. Future research is planned using an acoustic optical system (AOS) to estimate target strength of dominant micronekton species (i.e. lanternfish, family Myctophidae). Target strength values are required to convert acoustic densities to estimates of biomass. Together these data will help to develop explanatory and predictive models for micronekton in the Ross Sea MPA.

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Using new satellite datasets modelling egg and larval transport of Antarctic Toothfish (D. mausoni) in the East Antarctic region

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Antarctic Toothfish (D. mausoni) is one of the fishery targets with economically high valued in the Southern Ocean. CCAMLR assesses Toothfish fishery to continue the sustainable fishery and evaluate its ecology and the role of toothfish in the Southern Ocean foodweb system. To manage a stable population size and understand the life cycle of toothfish, the behaviour of the early stage of toothfish (i.e. egg and larvae) is essential knowledge.
In the East Antarctic region, Banzare Bank (BB, South part of Kerguelen Plateau) and continental slopes are hypothesized as main spawning grounds, and continental shelves are estimated as nursery grounds. However, egg and larval transport mechanism of toothfish in the East Antarctic region is still poorly known. We present the first result of particle tracking model for the oceanic transport of the early stage of toothfish released from (i) the BB and (ii) continental slopes with key ocean dynamics inducing the successful transports in the East Antarctic region. This model uses 8-year multiple satellites derived datasets to advect particles over altimately ice-free velocity filed.
Our result indicates the BB is the weak source of larvae for hypothesized nursery grounds, and continental slopes are strong sources by quick local inner-shelf transports through three-year simulations. The changes in oceanic positions and structures of cyclonic gyres and series of eddies affect the level of successful connections between spawning and nursery grounds over continental slopes and shelves.

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Larval and transformation-stage growth rates of Electrona antarctica (myctophid fish) in the Southern Ocean

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Myctophid fish provide important trophic links between zooplankton and higher predators in the Southern Ocean. Electrona antarctica is the most abundant myctophid in the high Antarctic zone, with its larvae found abundantly in the upper layer of the circumpolar deep-water during summer. However, the hatching season of E. antarctica has heretofore remained unelucidated. We analysed growth rates of E. antarctica during the larval and transformation stages using otolith increments to estimate hatching dates. Fish were collected using a ring net (mouth diameter: 1.60 m, mesh size: 500 µm) off Wilkes Land (East Antarctica) during January 2017-2020. Samples were preserved in 90% ethanol. The body length (BL) of fish was measured before fixation. Sagittal otoliths were extracted from seventy-four larvae. Daily rings in the otoliths were counted under a light microscope to estimate age in days (Age). The growth rate was estimated using regression analysis. The relationship between the BL and Age of larval E. antarctica (5.7-16.9 mm BL) was expressed by a linear equation: BL = 5.3 + 0.67×Age (R^2 = 0.82). The estimated hatching dates of E. antarctica in 2017 were between late December 2016 and mid-January 2017. A previous study estimated the growth rate of juvenile and adult E. antarctica to be 0.063 mm/day. This disparity between results implies a decrease in growth rate after the transformation stage (19-21 mm BL). In this presentation, the growth rate from larval to juvenile stages through transformation will be shown by adding transformation stage fish sampled in 2018-2020.

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Hormonal analysis provides new insights on reproductive features in Antarctic notothenioids: a trial in Lepidonotothen nudifrons

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The knowledge of reproductive biology in notothenioids arises exclusively from macroscopic and histologic descriptions, without the complement of hormonal analysis. Our study provides for first time in Lepidonotothen nudifrons adult females, information on oocyte growth and change in testosterone and estradiol plasma levels throughout the ovarian growth. Sampling included near 100 specimens caught at Potter Cove (PC), South Shetland Islands (SSI), from November to late March of 2016-2018. Histological analysis confirmed the macroscopic characteristic of two distinct cohorts of oocytes: one leading clutch (Lc) of large orange vitellogenic oocytes, to be spawned in the upcoming reproductive season, and a second clutch of smaller whitish previtellogenic oocytes. In March, females (n=17) attained gonado-somatic index of 13-20% (16.73±4.20), total fecundity of 2196-4652 oocytes/female (3209±740) and Lc oocytes of 1.7-2.1 mm. The Lc oocytes growth was significantly associated with photoperiod, with no diameter variation until the summer solstice, when they began to grow linearly with an estimated rate of 0.01 mm/day. Testosterone and estradiol increased together with the oocyte growing throughout the analyzed seasons, with a higher rise rate during March. The significant plasma level increase of both sex steroids observed in March and the reproductive effort data suggest that: (1) specimens were at a late vitellogenesis stage just prior to the oocyte final maturation in March, and thus L. nudifrons spawning period might onset from this month at SSI; (2) PC is likely a spawning site for L. nudifrons, which reinforce the hypothesis that nearshore areas are spawning grounds for some notothenioids.

600

Movements patterns of tagged Antarctic toothfish Dissostichus mawsoni

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Antarctic toothfish (Dissostichus mawsoni) and Patagonian toothfish (D. eleginoides) are generally considered to be non-migratory species, with previous tagging studies indicating individuals typically only move distances of less than 20 km from their initial point of observation. Most studies have focused on Patagonian toothfish with research on the distribution and behaviour of Antarctic toothfish being relatively limited. Toothfish tagging studies in the Southern Ocean have been designed and implemented as mark-recapture approaches to estimating population size data from 3835 recaptured D. mawsoni to analyse movements of patterns of this circum-Antarctic species. Results indicate that while the median distance between tagging and recapture was 22km, regardless of the time-at-liberty, 10% of individuals moved > 200km and 4% moved >500 km. The direction of movement for those fish that moved > 500 km shows a distinct bias towards an anti-clockwise direction around the Antarctic continent, possibly following the Antarctic coastal current. Tagging studies, although implemented for population size estimation, can also provide insights into movement patterns, population linkages and basic ecology of fish species, particularly where other sources of data are not available.

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Bycatch of fish in the krill fishery: insights into Southern Ocean pelagic fish assemblages

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The majority of fish research in the Southern Ocean is directed towards nearshore and commercially exploited species. As a consequence there is relatively limited sampling of pelagic fish assemblages. CCAMLR requirements for scientific observer coverage in the pelagic fishery for Antarctic krill have resulted in over 30 000 samples inspected for fish bycatch and over 90 000 fish identified and measured. This has increased the information available on fish bycatch around the Antarctic Peninsula, South Orkney Islands and South Georgia where icefish and nototheniids were found most frequently. Species-specific differences in geographic distribution patterns are apparent with some taxa such as Chaenodraco wilsoni found predominantly in the Antarctic Peninsula whereas others taxa, such as Lepidonothen larseni, have a more ubiquitous distribution. Length frequency distributions of bycatch fish typically have unimodal distributions with a modal length of less that 10cm although multi-modal distributions are apparent for some taxa. These data provide the basis for an improved understanding of the ecosystem impacts of the krill fishery as well as providing the basis for approaches to mitigate the bycatch of fish in the krill fishery. These data are collected throughout the year and provide a unique source of data on the pelagic fish assemblage in a key part of the Southern Ocean.

1394

Diet of the bald notothen (Trematomus borchgrevinki) in the fast ice zone of Terre Adelie

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Notothenioid fish are the dominant group of mesopredators in the high-Antarctic. Obtaining information regarding their ecological role is key for understanding potential success or failure under changing Antarctic conditions. Diet analyses can reveal information about a species' functional placement in the food chain and direct observations of predation events and use of resources. Trematomus borchgrevinki, the bald notothen, was collected in the coastal fast-ice zone of Terre Adélie, Antarctica, during summer. Stomach contents were identified, sorted, and analyzed using percent frequency of occurrence (%F). The calanoid copepod Paralabidocera antarctica was present in the highest number of stomachs (%F = 69) followed by krill (%F = 38). Larger prey occurred more frequently in the fish stomachs as standard length of fish increased. Comparisons with other diet studies indicate that T. borchgrevinki is plastic in its dietary choice and may cope well with changing Antarctic conditions, although this is contingent upon the continued presence of favourable prey.

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Myctobase: a circumpolar database of mesopelagic fish creates opportunities for new insights into mesopelagic prey fields

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Deep pelagic ecosystems are under-represented in databases of marine biodiversity, despite holding the largest biomass of organisms on Earth. Mesopelagic fishes dominate global biomass estimates possibly contributing up to 10% of the primary production at mesopelagic depths. In the Southern Ocean, the importance of mesopelagic fishes in alternative energy pathways has been established and can dominate the transfer of energy to pelagic top-predators in specific regions and seasons. The intensifying challenges posed by climate change has heightened the need for long-term datasets, on biomass-dominant species, across varying spatial domains and time scales, in addition to baseline data. Biodiversity informatics provides a powerful and timely tool for the integration of scattered and unpublished data. Here, we integrate existing catch data for mesopelagic fishes from survey voyages by SCAR nations to create a purpose-built database, Myctobase. We have collated species-specific data on life stage, length, weight, abundance and associated sampling methods from 13 different voyages. We aim to use this database to develop explanatory and predictive models of the environmental determinants of biomass for key myctophid species accounting for differences in survey methodology. Here, we present preliminary results from the Atlantic and Indian sector of the Southern Ocean. This research yields new insights into the biophysical determinants shaping patterns of biomass and abundance of mesopelagic fishes. We anticipate that Myctobase will continue to grow into a fully circumpolar database with continued collaboration from across the scientific marine community.

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Ontogenetic shifts in the diet of Bathylagus antarcticus (Microstomatidae) in the Indian Ocean sector of the Southern Ocean

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Mesopelagic fish play important roles in Southern Ocean foodwebs, linking zooplankton with higher predators. Although the Antarctic deepsea smelt Bathylagus antarcticus has a large biomass in the Indian Ocean sector of the Southern Ocean, its dietary habits remain unclear. The present study examined gut contents of larval to adult-stage B. antarcticus to reveal ontogenetic shifts in diet. Fish were collected off Vincennes Bay (East Antarctica) during January 2019 and 2020. The gut contents of the sixty-five fish (27.5 – 149.3 mm in body length, BL) analysed in this study included amphipods, chaetognaths, copepods, euphausiids, ostracods, polychaetes and pteropods. In the small fish size class (27 – 50 mm BL), copepods were the most important items both in volume and frequency of occurrence (61% and 73%, respectively). However, copepods were less important in volume (22%) and frequency (13%) in the larger 70-90 mm BL size class. Instead, other zooplankton including amphipods, euphausiids and pteropods comprised higher proportions of gut contents. The maximum size of B. antarcticus food items increased with mouth size growth. Therefore, 27 – 70 mm BL B. antarcticus mainly ate copepods, with the main trophic source changing to larger zooplankton at >90 mm BL. The dietary shift from copepods to larger zooplankton was related to increases in mouth size. Ontogenetic vertical migration from the upper mesopelagic to deeper layers is likely to explain this diet shift. We also present here results of DNA analysis applied to unidentified gut contents.

1110

Fisheries science at Heard Island and McDonald Islands on the Kerguelen Plateau

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Commercial fishing for Patagonian toothfish (Dissostichus eleginoides) and mackerel icefish (Champsocephalus gunnari) at Heard Island and McDonald Islands on the Kerguelen Plateau started in 1997. Patagonian toothfish is a large, long-lived and relatively late-maturing predator that can be found from 100 m to over 2500 m depth, while icefish is a medium-sized, short-lived zooplanktivore that lives on the shallow shelf up to around 350 m depth. The main focus of research has been to deliver management advice for CCAMLR on ecologically sustainable catch limits for target and bycatch species and mitigation of fishing impacts on the ecosystem. However, the comprehensive data sampling program from the fishery which includes logbook returns on catch and effort, an annual random stratified trawl survey (RSTS), a tagging program, and a variety of data collected by observers with 100% observer coverage on all vessels and fishing trips, has also allowed to improve our understanding of the biology of many species on the Kerguelen Plateau. Here, we summarise some insights into the distribution, movement patterns, ecology and population dynamics of fish and elasmobranch species on the plateau from this research.

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SESSION 23

FROM DRONES TO SATELLITES: THE USE OF REMOTE SENSING IN ANTARCTIC ECOLOGY AND CONSERVATION

Heather Lynch
Alex Borowicz

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Using RPAS in assessing Southern giant petrel Macronectes giganteus nests on King George Island - Antarctica during the Southern summer 2020.

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The importance of using remotely piloted aircraft systems (RPAS) in conservation as a tool for the wildlife study in places of restricted accessibility is highlighted. During the southern summer 2020, in the framework of the Peruvian Antarctic Campaign ANTAR XXVII, the mapping of a Southern giant petrel colony located on King George Island was carried out using RPAS. The use of this tecnology allowed georeferencing each nest, counting and categorizing individuals and determining densities in that locality, as well as the geographic features related to their habitat. This method also provides the possibility of repeating the count and recording of the above mentioned parameters, even by different evaluators, without causing an impact on individuals, which constitutes an important tool for the study of this species and its conservation in the area.

1651

Whales from space in the Antarctic: Opportunities and challenges

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Understanding spatial and temporal presence of whales on the West Antarctic Peninsula (WAP) is necessary to aid marine conservation and management. However, traditional surveys, either by planes or boats, are frequently too expensive, and as a consequence such surveys are often infrequent. Very High Resolution (VHR) satellite imagery offers a means of gathering data more frequently than traditional in situ methods. Previous research has detected whales in imagery, both at-sea and on the coast and when stranding events occur. However, further investigation into the application of this technique are needed. Here we use five WorldView-3 (31cm) images of Wilhelmina Bay, WAP, captured over the austral summer of 2018/19, covering the known humpback whale season (December to March). Systematic manual scanning of these images by three trained observers revealed whale-features, such as long white flippers, bubble nets, and blows. Detection of whale-like features on each image was congruent between observers, with the number of definite features recorded by observers typically being within 2.54±2.42 of each other. Differences in classifications emerged between observers when features were harder to distinguish from surface conditions. Densities estimated from these manual surveys increased throughout the season, peaking in early March (2.99 ±1.68 whales per km2). However, detection was also influenced by levels of sea ice and increasing darkness late in the season, with surface wind and swell also influencing detectability. These observations demonstrate the growing potential of VHR as a platform to monitor whales on the WAP.

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Using drone technology for improved Antarctic Specially Protected Area (ASPA) management in Antarctica

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For the first time, we demonstrated the use of remotely piloted aircraft (RPA) technology in directly informing Antarctic Specially Protected Area (ASPA) management. Our work provides the means for undertaking rapid and low-impact ASPA surveys that are cost effective and highly repeatable. The repeatability of these surveys is of particular value to environmental managers and policy makers. RPA surveys provide quantifiable information on human impact within ASPAs as well as changes that occur from natural variability or climate such as the change in vegetation cover and species distribution.

In this study, we used a custom-built multirotor RPA to conduct systematic autonomous aerial surveys over Botany Bay ASPA 154 in January 2018. The RPA system was customised for high altitudes, sub-zero temperatures and high wind conditions with specialised multispectral and hyperspectral sensors. GNSS surveys were conducted to provide ground control points to improve the accuracy and precision of the models and vegetation maps produced. The resultant vegetation maps provided a much higher level of accuracy and a far greater degree of confidence in the spatial coverage of the vegetation that is being protected in the ASPA. The revised management plan for ASPA 154, including the new vegetation maps, was submitted to the 42nd ATCM and was adopted unanimously by the Parties (ATCM Measure 6, 2019).

The approach we used is highly relevant to monitoring change at Antarctic sites, ensuring the values being protected remain intact and that management actions remain relevant in light of any observed change at the site.

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Frontiers and challenges at the intersection of cetacean populations, deep learning, and high-resolution imagery in the Antarctic

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The ongoing recovery of Antarctic cetacean species is a process of interest to management, conservation, and ecological forecasting, yet highly mobile and wide-ranging predators such as these are challenging to study in this environment. Research efforts local to permanent stations provide high temporal resolution information at the expense of spatial extent, whereas occasional at-sea and aerial surveys provide information over larger areas, but at a coarse temporal grain. Meanwhile many areas of predator habitat remain virtually unsurveyed. We demonstrate the potential for very high-resolution satellite imagery analysis to supplement more traditional survey methods in the Southern Ocean. Using deep learning methods, we describe an aerial imagery-trained model to detect large cetaceans in satellite imagery, finding 100% of whales in our test imagery, and misclassifying only 10% of images of open water as whales. Numerous challenges remain to wide-scale implementation broadly, and specific challenges remain to successful implementation as a survey method in the Antarctic.

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Faster, greener, and more competitive? Quantified vegetation change over 55 years in continental Antarctica

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The unique Antarctic terrestrial vegetation may serve as a sensitive early warning system in understanding ecosystem responses to climate change. In situ data have revealed distribution shifts, and many species have expanded their ranges in a warming Antarctic. In the terrestrial realm, suitable habitat availability is predicted to increase by ~25% in the next century and along the Antarctic Peninsula, warmer temperatures boost terrestrial ecosystem productivity as shown for lichens, mosses and vascular vegetation.
Any such information cannot easily be translated to continental sites, where water availability and microclimate dictates ecosystem productivity. There is a need to assess changes in vegetation cover, composition and distribution shifts in continental Antarctica if we aim to improve our understanding of Antarctica's terrestrial biosphere in the context of global carbon cycles and ecosystem resilience. This unique study compares detailed vegetation survey data from 1962 and 2004 at Cape Hallett, Victoria Land with manual field surveys and high-end hyperspectral imagery taken in 2018 representing the longest available time period for assessing vegetation change in Antarctica. We evaluate changes in the expansion of vegetation cover by applying a random forest model to a hyperspectral data cube to create a high-resolution map of the local vegetation and assess its resilience by combining remote sensing and physiological measurements testing the physiological acclimation capacity of the local moss species. Our results indicate a drastic increase in moss cover indicating a higher water availability with unknown consequences for the productivity, associated ecosystem services and ecosystem functioning in this fragile habitat.

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Optimizing ocean colour remote sensing measurements in the West Antarctic Peninsula

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Ocean colour remote sensing (OCRS) has long been used to study phytoplankton in coastal and oceanic regions. As OCRS enables the acquisition of continuous data with good spatiotemporal coverage, it is considered a vital tool towards studying remote ecosystems, where in-situ data is scarce. In the Antarctic Peninsula, however, two main limitations have prevented a definite implementation of OCRS: common ice and cloud coverage. Plus, ocean colour algorithms have been seen to consistently underestimate chlorophyll a concentrations in Antarctic waters. This work will seek to use two synchronous 10-year in-situ and OCRS datasets to evaluate and improve the performance of ocean colour remote sensing as a tool for evaluating phytoplankton biomass off the Antarctic Peninsula. On the one hand, the Ocean Colour – Climate Change Initiative chlorophyll a product will be used, since it offers multi-sensor, mid-long-term data with good spatiotemporal resolution. Plus, this product is error-characterised and its algorithm takes into account the seawater bio-optical properties of a given pixel. On the other one, yearly in-situ campaigns comprising of biological, physical and bio-optical data will be used to validate and finetune OCRS data. Specific validation exercises will be performed, considering regions, cruises, dominant water class and dominant phytoplankton groups. Solutions to increase performance will be tested using novel methods and its results presented. Results are expected to pave the way towards more accurate OCRS measurements in the Antarctic Peninsula, contributing to the establishment of OCRS as a definite tool for studying phytoplankton in Antarctic waters.

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Aerial surveys for penguin populations on the Antarctic Peninsula

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There are 18 species of penguin, six of which breed regularly on the Antarctic Peninsula and across the Scotia Sea. Populations in this region have been changing over the past century, with reported declines for Adélie and chinstrap penguins, but increases for gentoos. However, considerable spatial heterogeneity exists in penguin population trends across long-term study sites.
The most up-to-date and most comprehensive population data for Antarctic penguins comes from the MAPPPD project (Humphries et al. 2017). This database includes all published data on Antarctic penguin populations.
Colony counts in MAPPPD for Adélie penguin breeding sites show that 98.5% of the regional population has been surveyed since 2004. In contrast, for chinstrap penguins, only 10.2% of the population has been surveyed since 2004, and that most of the population has not been counted in over 30 years. Counts for gentoos are intermediate, with 83.4% of the population having been surveyed since 2004, but with most of the remainder being older than 30 years.
Up-to-date data are vital for management purposes, including managing the fishery for Antarctic krill, understanding the regional impacts of climate change, and understanding how ecosystems change, given the ongoing recovery of marine mammals. New tools are needed if managers are to adequately understand penguin population trajectories. The British Antarctic Survey has therefore initiated an aerial photographic survey programme to update colony estimates for more than 50 of the larger colonies. In this poster we report initial findings and explore some of the challenges for updating penguin population estimates.

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Discovery of new colonies reveals good and bad news for emperor penguins

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The distribution of emperor penguins is circumpolar, with 54 colony locations currently reported of which 50 are currently extant. Here we report on eight newly discovered colonies and confirm the re-discovery of three breeding sites, only previously reported in the era before Very High Resolution satellite imagery was available. This represents an increase of ~20% in the number of breeding sites, but, as most of the colonies are small, these sites only increase the total population by around 5-10%. The discoveries have been facilitated by the use of Sentinel2 satellite imagery, which has a higher resolution and more efficient search mechanism than the Landsat data previously used to search for remote colonies. Some of the colonies are very small, indicating that considerations of reproductive output in relation to metabolic rate during huddling, is likely to be of interest. Some of the colonies exist in offshore habitats, something not previously reported for emperor penguins. Comparison with recent modelling results show that the geographic locations of all the newly found colonies are in areas likely to be highly vulnerable under business-as-usual greenhouse gas emissions scenarios, suggesting that population decreases for the species will be greater than previously thought.

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Seals from Space: the monitoring of ice seals and sea ice habitats by remote sensing

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Antarctic pack-ice seals (APIS) are long-lived, upper trophic level predators and amongst the largest consumers of Antarctic krill. Therefore, the monitoring of APIS populations can indicate changes in the Antarctic ecosystem. However, APIS inhabit the inaccessible sea ice zone, making traditional surveys (i.e., ship/aerial) logistically difficult. Because of these challenges, reliable population estimates and habitat information for ice seals are lacking. To overcome these limitations, very high-resolution (VHR) satellite and unmanned aerial vehicle (UAV) imagery will be used to discriminate ice seals for counts at local scales and identify habitat hotspots. This involves identifying species classification parameters; extracting sea ice characteristics; constructing habitat models to explain population dynamics and predict responses to environmental change.

Here, we present details of two approaches for sea ice habitat classification for seals i) a citizen-science based manual approach and ii) an automated computer vision approach resulting in the first VHR sea ice classification tool. We also discuss the analysis of in-situ and satellite seal surveys. The outputs from the sea ice classification and seal counts are combined into an ecological model to explain seal distribution in terms of social behavior and environmental variables. Resulting insights into the habitat preference and distribution of seal colonies will enable us to better predict future responses to climate change. Given that sea ice volume is predicted to decline significantly by the end of the century, the efficient monitoring of APIS and their habitat is pivotal to polar marine conservation.

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Green Antarctica - remote sensing reveals snow algae as important terrestrial carbon sink

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In the limited terrestrial ecosystems of Antarctica, all photosynthetic organisms will make a significant contribution to the ecology of their habitat. Blooms of snow algae are known to occur annually in Antarctica but, until now, neither their scale nor contribution have been quantified. We present the first estimate of the green snow algae community biomass and distribution along the Antarctic Peninsula. Using Sentinel-2 satellite imagery from 2017-2019 and field data collected over the same period, we identified 1679 blooms covering approximately 1.95km^2 of snow in a season. Field measurements enabled us to calculate that this represents a dry biomass of 1327 tonnes (479 tonnes of carbon). Spatial analysis suggests that snow algal range is limited to areas with average positive degree days in the austral summer, and that their distribution is strongly influenced by nutrient inputs from the ocean via marine vertebrates, with 60% of the blooms identified found within 5 km of penguin colonies. Our findings suggest a warming Antarctic Peninsula will likely to lose a majority green snow algae blooms, as 62% of these were on small islands with no high ground for upward range expansion. However, as bloom area and elevation were observed to increase towards the north of the Peninsula, we suggest a parallel expansion of blooms on larger landmasses, close to bird or seal colonies. This increase is predicted to outweigh significantly the biomass lost from small coastal blooms and result in a net increase in snow algae extent and biomass as the Peninsula warms.

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Fine-scale seasonal trends in abundance and distribution of pinnipeds in the Palmer Archipelago

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Unoccupied aircraft systems (UASs) enable rapid, on-demand remote sensing of environments and their fauna with less disturbance than on-the-ground surveys. In mid–late austral summer 2020, UAS surveys were conducted near Palmer Station, Antarctica, over known terrestrial haul-out locations of southern elephant seals (Mirounga leonina) and Antarctic fur seals (Arctocephalus gazella). Flight plans were implemented to (1) map the substrate and topography of coastal environments and (2) count and locate pinnipeds every 5–10 days. Mapping and pinniped surveys collected high resolution photo-sets with ground sampling distances ranging from 1.5–4 cm. Orthomosaic products and digital surface models were produced using standard 'structure from motion' workflows. Natural ground control points were collected with a survey-grade GPS at select sites to (1) estimate the error of unreferenced photogrammetric products and (2) produce georeferenced map products. Analysts visually detected and identified M. leonina and A. gazella by pelage and morphology across a range of substrates, alongside sporadic occurrences of pagophilic seals (Lobodon carcinophaga and Leptonychotes weddellii). Sequential surveys revealed fluctuating but persistent occupancy of M. leonina through mid–late summer and a precipitous arrival of A. gazella in late summer. All species exhibited distinct spatial affinities, with M. leonina aggregating at beaches and wallow sites, A. gazella dispersing throughout coastal landscapes, and pagophilic seals hauling out exclusively at low-lying beaches and snowbanks. These surveys, conducted as part of the Palmer Station Long-term Ecological Research Program (LTER) represent the first efforts to comprehensively study pinniped abundance and distribution in the Palmer Archipelago.

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Detection and community-level identification of microbial mats in the McMurdo Dry Valleys using drone-based hyperspectral reflectance imaging

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The reflectance spectroscopic characteristics of cyanobacteria-dominated microbial mats in the McMurdo Dry Valleys (MDV) were measured using hyperspectral point and line-scan spectrometers aboard unmanned aerial systems (UAS; RPAS, UAV, or drone) to determine whether mat presence, type, and activity could be mapped at a spatial scale sufficient to characterise inter-annual change. Mats near Howard Glacier and Canada Glacier (ASPA 131) were mapped, and mat samples were collected for DNA-based microbiome analysis. Although a common broad-band spectral parameter (pNDVI) identified mats, it missed mats in comparatively deep (>10 cm) water or on bouldery surfaces where mats occupied fringing moats. A hyperspectral parameter (B6) did not have these shortcomings and recorded a larger dynamic range at both sites. When linked with colour orthomosaic data, B6 band strength is shown to be capable of characterising the presence, type, and activity of cyanobacteria-dominated mats in and around MDV streams. When we applied B6 band analysis to line-scan hyperspectral imagery, we were able to map the extent and activity of distinct mat types at decimeter resolution over more than five hectares. Microbiome analysis of the mat samples revealed that dominant cyanobacterial taxa differed between spectrally distinguishable mats, indicating that spectral differences likely reflect underlying biological distinctiveness. Our findings demonstrate that combined rapid-repeat hyperspectral measurements can be applied to monitor the distribution and activity of sentinel microbial ecosystems, which are expected to respond rapidly to change in meltwater availability associated with warming.

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A convolutional neural network architecture designed for the automated survey of seabird colonies

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Satellite imagery is now well established as a method of finding and estimating the abundance of Antarctic penguin colonies. However, the delineation and classification of penguin colonies in sub-meter satellite imagery has required the use of expert observers and is highly labor intensive, precluding regular censuses at the pan-Antarctic scale. Here we present the first fully automated pipeline for the segmentation and classification of high-resolution satellite imagery. Our method leverages site-fidelity by using images from previous years to improve classification performance but is robust to georegistration artifacts imposed by mis-alignment between sensors or terrain correction. We use a segmentation network with an additional branch that extracts the useful information from the prior mask of the input image. This prior branch provides the main model information on the location and size of guano in a prior annotation yet automatically learns to compensate for potential misalignment between the prior mask and the input image being classified, leading to a 44% improvement (mean IoU increasing from 0.34 to 0.48) over previous approaches. While trained for the classification of Adélie penguin colonies, this method can be adapted for other ecological applications where the dynamics of landscape change are slow relative to the repeat frequency of available imagery and prior information may be available to aid with image annotation.

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Combining Underwater Hyperspectral Imaging and Structure-from-Motion digital photogrammetry to improve benthic habitat assessments

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Advancements in Underwater Hyperspectral Imaging (UHI) and Structure-from-Motion digital photogrammetry (SfM) are rapidly improving benthic studies, this research investigates its usefulness for increasing our knowledge of Antarctic benthic ecosystems. Hyperspectral imaging collects data across hundreds of bands of light detecting subtle differences in the way benthic objects absorb and reflect light conferring them a unique 'spectral signature'. Furthermore, UHI can achieve mm/pixel spatial resolution providing researchers enough information to identify organisms based on more than what is visible to the naked eye and can enhance automated methods for benthic habitat mapping. SfM complements the high-resolution data of UHI by creating 3-D structure models of benthic organisms and habitats providing additional taxonomic features and structural complexity metrics of the benthos. Currently, there are no studies applying UHI in tandem with SfM for Antarctic benthic organism identification. By collecting in situ benthic specimens and through the additional development of a controlled lightning-laboratory setup, this study will explore the potential of UHI spectral signatures with 3-D metrics for organism identification. We hypothesize that efforts in bringing these two technologies together will enhance biodiversity studies and improve our ability to detect changes in benthic habitats. Results will provide the basis to further upscale these imaging techniques onto underwater platforms for improved and automated Antarctic benthic habitat assessments.

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Remote Sensing of Southern Ocean Phytoplankton in a Warming World

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Marine phytoplankton play an essential role in the structure and functioning of the Southern Ocean (SO). Being short-lived and fast growing, phytoplankton can respond rapidly to changes in sea surface temperature (SST). Concurrent with long-term small increases in average SST, the more dramatic increases in short-term warming events, that is marine heatwaves (MHWs), are very likely to be attributable to global warming (IPCC 2019). Little is known about how oceanic warming coupled with MHWs will affect SO phytoplankton. This research aims to address this research gap by quantifying the effects of MHWs on chlorophyll-a (chl-a) concentrations, a proxy for phytoplankton biomass, using satellite measurements of ocean colour.
All extreme summertime MHW events across the SO were identified from 2002-2018. These short-term anomalies were correlated with chl-a using a ‘control vs. impact’ experimental design. A MHW identification procedure based on Hobday et al. (2016) was used, defining MHWs as anomalously warm events during which temperatures exceed the 90th percentile and persist for >5 days. Based on Anova and correlation analyses, I found that these extreme summer MHWs increased chl-a in the SO, and that this increase was stronger in regions with lower average SST and higher ice cover.
The results suggest that a focus on average changes over long periods and wide areas could overlook ecologically important short-term changes associated with MHWs. These events, superimposed on long-term climate change, may eventually reach a tipping point in the SO with large-scale shifts to entire communities at the base of the food web.

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Mapping emperor penguins by drone

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The Southern Ocean is increasingly influenced by humans. Climate change and fisheries are changing its ecosystem and are at the same time influenced by its condition. However, data on the state of this ecosystem are difficult to obtain. Penguins are among the few of its elements visible on the surface, particularly emperor penguins, which breed on seasonal sea ice. This and their function as predators in the food web makes them an important indicator of the state of the Southern Ocean ecosystem.
This species does not only breed in difficult to access places, it also has a high mobility during the breeding period, making data on the size of penguin colonies difficult to acquire. The use of drones offers the possibility to collect data even from large colonies in a relatively short period of time.
From November to January 2019/20 we mapped the emperor penguin colony in Atka Bay, Dronning Maud Land at three different times during the season with a quadrocopter drone. The main colony is located on the sea ice at the western edge of Atka Bay. Since emperor penguins, unlike other penguin species, do not build nests, they constantly change their position and separation into different subcolonies depending on current weather conditions is common. By using a drone, it was also possible to locate and record a relatively mobile and remote subcolony on the ice shelf.
We present mapping results and share our experience on the use of drones under the harsh climatic conditions of continental Antarctica.

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Obtaining reliable centimetre-resolution predictions of biologically relevant temperature variation in the canopy of moss turfs

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The majority of Antarctica's terrestrial biodiversity exists no more than a few centimetres above the ground- this being the approximate canopy height of moss beds which harbour much of the continent's floral, fungal, invertebrate and microbial diversity. For this reason, surface conditions are disproportionately important for Antarctic ecology. Automated weather stations (AWSs) in Antarctica record the conditions of weather at heights upwards of 1.5-m above the surface, and are often strongly misrepresentative of surface conditions, which can vary substantially across very small spatial scales due to surface micro-topography. Despite this, observations from AWSs are often used as predictors or explanatory variables in ecological studies, as long-term observations at the surface don't exist. Applying previously described biophysical formulae and UAV LiDAR, this study presents a physical downscaling approach for coarse-resolution satellite-derived radiation data, and a physically parameterised energy balance equation driven by AWS observations for remotely and reliably predicting canopy temperatures of moss beds, both spatially and temporally, at a centimetre resolution. Observations of moss canopy temperatures were obtained in situ from the Coppermine Peninsula Antarctic Specially Protected Area (ASPA No. 112) in the Maritime Antarctic. Validated against these observations, the model predicts canopy temperatures largely in agreement with measured temperatures and has a RMSE of 2.1°C. Modelled and measured temperatures correlate with an R2 of 0.71 across 956 corresponding data points. This study presents a promising method for obtaining biologically relevant spatially explicit information from point sources in Antarctica, and can potentially be applied in a range of ecological studies.

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The behavioural responses of emperor penguins to drones

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The increasing usage of UAVs by researchers, TV- and movie production teams and private persons which has been reported during the last years is even reaching remote Antarctic regions with pristine ecosystems. Until now, there is no information on whether and how species living in such environments, like the emperor penguin, are impacted by the application of this technology. In consequence, it is almost impossible for national competent authorities to assess the possible environmental impacts of the UAV usage in the proximity of wildlife.
To investigate the behavioural response of emperor penguins and their chicks to UAVs, we conducted horizontal overflights in different altitudes ranging from 20 to 150 m above the animals as well as direct vertical approaches. We used two UAV types - one quadrocopter and one fixed wing UAV. During all flights, three separated groups of penguins within the colony were video recorded from the shelf ice at a distance of about 100 to 300 m. We also conducted experiments on the response to humans on foot to compare both kinds of disturbances. All experiments were accomplished from November 2019 to January 2020 at the emperor penguin colony at Atka Bay, Dronning Maud Land.
The recorded data are currently being analysed and the results will be presented. Preliminary insights into the data hint towards a strong reaction to direct human contact, while UAV flights cause less reaction. Within those, vertical approaches seemingly cause a stronger response than horizontal flights, which induce few reactions even at low altitudes.

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UAS-based micro-scale photogrammetric modelling of topographic abiotic factors for microbial communities. A case study of the Sør Rondane Mountains, East Antarctica.

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The Antarctic ice-free areas are among the most extreme environments on Earth. Yet, their soils harbor diverse microbial communities, varying significantly between regions and micro-climatic conditions. Some of these, such as biological soil crusts (biocrusts) provide multiple ecosystem services by increasing soil fertility and stability, thus influencing biogeochemistry and erosion. Previous studies showed topographical factors influencing the community structure of soils, like orientation, elevation or the daily received solar energy. Nevertheless, the factors responsible for driving the microbial diversity and structure of inland nunataks of East Antarctica are still poorly understood. This study aims to determine topographical parameters through very-high-resolution 3D modelling of micro-community habitats. Following the sampling of soils (from barren bedrock to substrates covered by biofilms and biocrusts), we deployed uncrewed aerial systems to survey several nunataks with structure-from-motion (SfM) near-surface remote sensing. While SfM is known for its limitations in homogeneous, low-contrast environments such as snow and ice, the chosen nunatak's rocky slopes provide ample structure for high resolution modelling.
The resulting point clouds and derived digital elevation models facilitate an in-depth characterization of soil habitats in regard to e.g. slope, roughness and exposure, as well as parameters derived from these. This will help to identify and understand potential topographic limiting factors for these communities. To our knowledge, this is the first two-centimeter-resolution model of a nunatak in continental Antarctica, promoting the application of this technology to other harsh environments and allowing for a detailed comparison of near-surface and satellite-based remote sensing in this structurally diverse environment.

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Exploring Applications of ICESat-2 to investigate Gentoo Penguin Range Expansion

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Gentoo penguins (Pygoscelis papua) are commonly considered ‘climate change winners’, as their populations have undergone rapid growth along the Western Antarctic Peninsula (WAP) since the early 2000s. Coincident with increasing regional population sizes, gentoo penguins have also established several new breeding colonies that have expanded their current home range further south along the WAP.

The advances in remote sensing have enabled the polar research community to use satellite technology to detect and estimate penguin colony size, as well as monitor suitable penguin habitat with respect to regional climate conditions and sea ice concentration. With the recent deployment of ICESat and ICESat-2 laser altimetry systems, researchers have a unique opportunity to detect and explore winter sea ice conditions using novel sensor platforms. Here we detail efforts to explore fine-sale changes in winter sea-ice conditions with respect to range expansion of marine predators such as gentoo penguins.

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Detailed site and contaminant characterisation using drones and ground based soil gas surveys across a perennial Antarctic snowpack and a legacy catchment at Casey station, Australian Antarctic Territory.

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UAV imagery and RTK GNSS data was used to create high resolution digital surface models and orthophotomosaics of two diesel contaminated sites at Casey station, East Antarctica, using Structure from Motion (SfM) techniques.

The presence of a thick cover of wind-blown snow and an underlying perennial snow-pack (> 4m depth) at one of the sites limited the ability of the field team to assess the extent of the diesel contamination through traditional techniques (such as the use of photo ionisation detectors and soil samples). The second site studied was from a well-studied legacy diesel spill near Old Casey station. Data from traditionally obtained soil and water samples, and from two high resolution passive soil gas investigations was combined with the detailed site survey data to identify specific sub-surface hydrocarbon contaminant migration pathways at Australia's Casey Station in Antarctica.

Contaminant surfaces were generated in ArcGIS Spatial Analyst using data from passive soil gas samplers to visualise hydrocarbon intensity within the context of a three dimensional model of surface snow and ground surface conditions. This helps reveal the dominant fuel migration pathways, how they relate to observed changes in surface snow and melt conditions and ground topography to better inform environmental risk and site management.

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SESSION 24

BIOPROSPECTING IN ANTARCTICA: A NEW FRONTIER OR A NOVEL THREAT?

Luiz Rosa

Peter Convey, Lize-Marié van der Watt, Siti Aqlima Ahmad

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Characterization of perchlorate reducing cultivable halophilic bacteria from Deception Island, Antarctica.

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Perchlorate (ClO4-) has several industrial applications and is frequently detected in environmental matrices at relevant concentrations to human health. Currently, perchlorate-degrading bacteria are promising strategies for bioremediation in polluted sites. The aim of this study was to isolate and characterize halophilic bacteria with the potential for perchlorate reduction. Two bacterial strains were isolated marine sediments on Deception Island, Antarctica. Isolates grew at concentrations up to 30% sodium chloride. The isolates tolerated pH variations ranging from 6.5 to 9.5, and perchlorate concentrations up to 10000 mg/kg. Perchlorate was degraded by these bacteria on percentages between 30 and 40 16S rRNA gene sequence analysis indicated that the strains were phylogenetically related to Psychrobacter cryohalolentis and Psychrobacter fozii specie. In conclusion, halophilic isolated bacteria the genus Psychrobacter from the marine sediments on Deception Island, Antarctica are promising resources for the bioremediation of perchlorate contamination.

Keywords: Antarctic, environmental face, halophilic bacteria, marine soil, perchlorate, toxicity

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Morphological characterization and composition of the tardigrades from the Media Luna island, Antarctic Peninsula

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The tardigrades are microscopic animals of at least 1 mm in length, better known as "water bears". Famous for its ability to withstand extreme conditions, when entering a dormant state, this resistance ability is called cryptobiosis. This ability allows them to conquer places as far away as Antarctica. Antarctica is a continent with a high interest in its extreme climatic conditions, getting the organisms that live there to develop strategies to withstand extreme conditions. For this reason, Media Luna Island was chosen as the study area. The study of Antarctic tardigrades was carried out by collecting samples of bryophytes on Half Moon Island on the Capa Negra Hill. The analysis of 10 samples allowed the identification of 4 main families of Hypsibiidae, Macrobiotidae, Echiniscidae and Calohypsibiidae tardigrades. Among these, we have identified the genera Diphascon, Hexapodibius, Hypsibius, Macrobiotus and Echiniscus. Some of the confirmed species have been previously reported in the Antarctic continent, but this is the first report on the Crescent Island for the species Diphascon victoriae, Diphascon rudnicki, Hypsibius conwentzii, Hypsibius dujardini and Macrobiotus aradasi.

Keywords: Antarctic, Crescent Island, identification, tardigrade

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Natural products from Antarctic marine benthic invertebrates

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Recent research in our lab is focusing at new approaches to study the natural products from Antarctic marine benthic invertebrates and their chemical ecology. A part of the description of the new compounds found and their bioactivities, we are looking at the production of these metabolites under situations of stress, trying to see changes in gene expression related to natural compounds synthesis. On the other hand, we are using CADD (Computer-Aided Drug Design) techniques to help us in the search for bioactivities for these compounds, and experimentally validating these results. For these, we are studying selected tunicate and gastropod molluscs compounds, but also sponges, bryozoans, and others. In this talk, a summary of these recent developments will be provided.

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Detection of antimicrobial activity and multiple resistance to antibiotics of bacterial isolates from pristine Antarctic soil samples and from rhizosphere of Deschampsia antarctica Desv.

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In this study, 50 bacterial isolates from pristine Antarctic soil samples from King George and Greenwich Islands (South Shetland Islands) and 25 bacterial isolates from the rhizosphere of Deschampsia antarctica Desv, were characterized for their antimicrobial activity and response to 21 antibiotics.
Antibiotic susceptibility was assayed following the disc diffusion method using different groups of antibiotics: penicillins, cephalosporins, carbapenems, aminoglycosides, quinolones, tetracycline, phenicols, sulfonamides, and trimethoprim. Antimicrobial compounds production by the Antarctic bacterial isolates were determined using the agar diffusion method, using Escherichia coli and Staphylococcus aureus as indicators of human pathogenic bacteria. The bacterial isolates were characterized by optical microscopy assays, biochemical batteries and fingerprinting using PCR with arbitrary primers.
The bacterial isolates studied showed resistance to 14 (67%) out of the 21 antibiotics tested. Three bacterial isolates (4%) were resistant to at least one antibiotic and 47 (63%) were multidrug-resistant. Additionally, 25 (33%) bacterial isolates do not show antimicrobial activity and were susceptible to all antibiotics studied. Finally, 27 (36%) bacterial isolates combining antimicrobial activity and multiple resistance to antibiotics. The bacterial isolates combining antimicrobial activity and multiple resistance to antibiotics are especially interesting, suggesting that these Antarctic bacteria are potential sources of genes encoding for antimicrobial compounds and antibiotic resistance. These two capabilities probably provide a competitive advantage to Antarctic bacteria to enable them to survive in a harsh environment. These microbial isolates are potential new sources of active compounds for the control of pathogenic microorganisms.

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Bioprospection of lipase producing microorganisms of biotechnological interest.

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Antarctic environments are promising locations for the search of novel bio-productos of biotechnological interest, because they are still little explored. In this study, the bacterial diversity and their cold-active lipolytic activity was investigated in different soil samples from Fildes Peninsula, King George Island. Microbial lipases and esterases are very prominent biocatalysts, which can carry out the hydrolysis and synthesis of ester compounds in aqueous and non-aqueous media. They have wide applications in industry such as detergent, environmental bioremediation and plant waste degradation, among others.
In this work, two primers random amplified polymorphic DNA (TP-RAPD) was used as a fingerprinting method to study the diversity of 74 isolates. Identification of those isolates that presented different pattern bands profiles was performed by sequencing of the 16S rRNA gene. The isolates were evaluated together for their lipolytic and/or esterase capacity according to the presence of halos around their colonies in tributyrin agar and tween esterase agar media respectively. The three isolates which developed the highest ratio between total diameter (halo and colony) and the colony diameter were selected for further studies of enzymatic activity. Lipolytic and esterase activity were studied varying temperature and pH, two key variables that affect enzymes performances. The results obtained in this work, aim to contribute to the knowledge of Antarctic microbial populations and their potential biotechnological application.

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Biotechnological lactic acid production from renewable resources by Carnobacterium sp. isolated from Uruguay Lake, King George Island

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Antarctic psychrotolerant bacteria are promising sources of bioproducts with potential biotechnological applications, such as the production of value-added chemicals. In this work, an isolate (LUA) from a water sample from Uruguay Lake (Fildes Peninsula, King George Island), identified as Carnobacterium spp. was studied for lactic acid production. In the first instance, the optimum growth temperature was determined in synthetic MRS medium. Then, the consumption of different sugars (cellobiose, galactose, xylose, arabinose and fructose) was studied using a modified MRS medium, in which the glucose was replaced by the carbon source evaluated. As LUA consumed glucose and xylose successfully, a lignocellulosic residue, eucalyptus sawdust, was evaluated as a carbon source for the production of lactic acid. This material is an attractive substrate for bioprocesses due to its low cost and little competence with foods. Eucalyptus sawdust hydrolysate fermentations were carried out in a 5 L-bioreactor with and without pH control. Higher productivity was found when the pH was mainteined at 6.5 (0.32 g/Lh-1 and 0.15 g/Lh-1 with and without pH control, respectively). These preliminary results showed that the LUA isolate is a promising strain for lactic acid production. Other operational conditions and culture compositions, such as fed-batch mode and higher initial sugar concentrations, will be studied to improve lactic acid yields.

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Herbicidal activity of Penicillium spp. species obtained from ice and marine sediment of Antarctica

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In this study we evaluated the capacity of Penicillium spp. isolates obtained from ice and marine sediment of Antarctica. Fungi obtained from ice were processed in potato-dextrose-agar (PDA) while those from marine sediments in malt extract agar (MEA) at 15°C for 15 days. After incubation, the mycelia were macerated and transferred to Erlenmeyers, frozen at -20 °C for 72 h, followed by lyophilization for 96 h. The metabolites were extracted with dichlorometane for ice fungi and ethyl acetate for marine fungi. The extracts of all taxa showed strong to moderate herbicidal activity at a concentration of 1 mg mL-1 against the models Lactuca sativa (lettuce) and Allium schoenoprasum (chives). The active Penicillium were identified as P. crhysogenum, P. tardochrysogenum, P. kongii, P. solitum and P. palitans by sequencing the ITS, beta-tubulin and RNA polimerase 2 regions. The results showed that the extracts remained active. In addition, some of them will be selected for Ultra-high performance liquid chromatography (UHPLC) analysis, in order to characterize chemically the herbicidal substances.

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Screening of antioxidant, anti-melanin and cytotoxic activities of microalgal extracts with cosmeceutical potential

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Microalgae are known to be a potential candidate for cosmeceutical applications in human health due to the beneficial properties of bioactive compounds and cosmetic products from natural sources. Microalgae of different region produces secondary metabolites as an adaptive mechanism to maintain survivability against environmental stress. These bioactive compounds were reported to possess antioxidant and anti-melanin properties. Therefore, the aim of this study was to determine the antioxidant properties, anti-melanin properties and cytotoxicity effects of extracts from 11 microalgae strain from the polar, temperate, and tropical regions. The results showed that microalgae from different region exhibit varied growth rate, biochemical composition and antioxidant activities. Higher growth (μ = 0.383 - – 0.474 d^(-1)) was demonstrated by tropical microalgae compared to the polar microalgae (μ = 0.196 – 0.246 d^(-1)). Similar trend was observed for chlorophyll-a, carotenoid and lipid content. In addition, extracts from tropical microalgae (Chlorella UMACC 003) were shown to have lower cytotoxicity (75.87 ± 2.22) on HaCaT cells. Thus, tropical microalgae are potential to be use in cosmeceutical applications.

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Xerophilic activities of fungi associated with the Antarctic plants Deschampsia antarctica and Colobanthus quitensis

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We evaluate the diversity and xerophilic potential of the fungi present in leaves, roots and rhizosphere of Colobanthus quitensis and Deschampsia antarctica living in different sites of South Shetlands Islands, Antarctica. A total of 683 fungal isolates were obtained and identified as 60 taxa. Only 15 fungi were recovered in both plants. The assemblage of D. antarctica showed higher values of diversity, richness and dominance when compared with those of C. quitensis. Pseudogymnoascus destructans colonized systematically leaves, roots and rhizosphere of D. antarctica. Mortierella antarctica, Mortierella gamsii, Penicillium commune, Penicillium jamesonlandense, Penicillium raistrickii, Penicillium spathulatum, Penicillium swecickii and Pseudogymnoascus destructans grew at concentrations of glycerol ≥72% (approximately 0.13 water activity). Our results indicated that Antarctic angiosperms shelter cold-adapted cosmopolitan and endemic fungi. In addition, the xerophilic fungi may produce compounds or shelter genes to further use in agriculture biotechnological processes to help plants with economic potential to growth in drought and cold conditions.

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Identification and diversity of fungi associated with the Antarctic marine invertebrate Ophiuroidea sp.

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In the present study, we access the cultivable fungi associated with Ophiuroidea sampled in Antarctic sea. The Ophiuroidea were sampled at the islands King George and Deception islands using box core device and 29 specimens were analysed. The animals were washed in sterile seawater, the arms were surgically removed, homogenized in 1 mL of sterile seawater, and 100 µL were plated on Sabouread Agar and Marine Agar. Forty-eight fungal isolates were identified, 14 from Ophiuroidea of King George Island and 34 from Deception Island. Aspergillus versicolor, Penicillium tardochrysogenum and Fusarium beomiforme were isolated from both areas. Penicillium rubens was only isolated from King George samples. Therefore, the conclusion is although the fungal diversity has been low, the taxa which were found were already described as source of bioactive compounds, can be used in future biological essays.

1641

Fungal associated with the Antarctic Diptera Parochlus steinenii (Gerke): taxonomy, ecology and search of bioactive compounds

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We accessed the fungal associated with the Antarctic chironomid Parochlus steinenii, which were captured on King George Island, Antarctica. Fifty individuals were surface disinfested and other 50 were not disinfested. All chironomids were plated on the DRBC, Sabouraud, and Minimum Medium media at 15 °C for up to 60 days. Forty-two filamentous fungi were obtained and identified as Penicillium and Aspergillus taxa. All fungi were growth using solid-state fermentation at 15 °C for 7 days. The media and fungi were lyophilised and submitted to extraction using the solvent dichloromethane. All fungal extracts obtained were submitted to detection of herbicidal activity against Lactuca sativa and Allium schoenoprasum. The extracts of P. chrysogenum UFMGCB 16811 (4.5±0), P. chrysogenum UFMGCB 16803 (3.5±0) and P. commune UFMGCB 16834 (4.0±0.7) had the best results against L. sativa. There wasn't inhibition against A. schoenoprasum. As conclusion, this work shows that the Antarctic chironomid Parochlus steinenii works as a good source for fungal species with high herbicidal activity.

1688

Temporal monitoring of fungal richness in moss 'fairy rings' on the Antarctic Peninsula

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In order to identify the fungi that may be causing the fairy ring disease, we monitored rings and the fungi present in two locations in the South Shetland Islands, Antarctica. Over two years, we collected, photographed, and counted rings on a carpet of Sanionia uncinata showing signs of the disease on King George Island. We also monitored a turf of the moss Polytrichastrum alpinum on Deception Island, visually apparently free of the disease. Over the period the incidence of rings increased on the S. uncinata carpet, while the P. alpinum turf remained visually unaffected. Using molecular approaches, we identified a rich fungal assemblage associated with the rings on S. uncinata, composed of 35 taxa and dominated by Vishniacozyma victoria, Pseudogymnoascus destructans, Cystobasidium larynges, and Mortierella sp. 1. In contrast, that associated with P. alpinum comprised only nine taxa, dominated by Penicillium sp. 1, Phenoliferia glacialis, Antarctomyces psychrotrophicus, and Mrakia frigida. Only P. glacialis, A. psychrotrophicus, P. destructans, Clathrosphaerina sp. 1, and Chalara pseudoaffinis were detected in association with both mosses, but none of these were dominant taxathere. However, fungal species previously reported as causal agents of the fairy rings were not detected. Our data confirm that the fungal assemblage of diseased carpets of S. uncinata is very different of that of non-infected P. alpinum. The high fungal richness associated with S. uncinata suggests that fairy rings may act as an initial gateway for fungal colonization that can then accelerate the spread of disease in mosses in Antarctica.

929

Diversity, distribution, and bioprospecting of bioactive compounds in fungi of glacial ice Antarctica

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In this study, we recovered and identified the cultivable fungi present in glacial ice fragments collected at nine sites across Antarctic Peninsula. We also evaluated their potential as producers of bioactive secondary metabolites, useful against neglected tropical diseases, and as the use of herbicides in agriculture. Approximately 20 kg of each bergy bit was collected and ice samples were broken into smaller pieces for surface decontamination with sodium hypochlorite at 5%, sterilized distilled water, and exposed to ultraviolet radiation. We filter 3 L of melted ice through of 0.45 µm membrane in duplicate. The membranes were placed in media different and incubated at 10 °C for 60 d. In total 66 isolates were collected, classified into 27 taxas of 14 genera. Penicillium palitans, Penicillium sp. 1, Thelebolus balaustiformis, Glaciozyma antarctica, Penicillium sp. 7, Rhodotorula mucilaginosa, and Rhodotorula dairenensis had the highest densities. The diversity and richness of the fungal community were high with moderate dominance. Penicillium species were present in all samples, with Penicillium chrysogenum showing the broadest distribution. P. chrysogenum, P. palitans, and Penicillium spp. had trypanocidal, leishmanicidal, and herbicidal activities, with P. chrysogenum having the broadest and highest capability. The ^{1}H NMR signals showed the presence of highly functionalized secondary metabolites. Despite extreme and ultraoligotrophic environmental conditions, glacial ice harbours a diverse fungal community, including species never before recorded in the Arctic and Antarctica. The genus Penicillium may represent wild fungal strains with genetic and biochemical pathways that can produce new secondary bioactive metabolites or not described.

994

Isolation of Antarctic and sub-Antarctic microorganisms, for the treatment of soils contaminated by hydrocarbons and their application in soils of Patagonia

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In sub-Antarctic and Antarctic regions it is possible to find historically contaminated soils with hydrocarbons. These soils are interesting for the isolation of bacteria.
Agar cultures of 13 samples of Antarctic soils chronically contaminated with hydrocarbons and 2 samples of subantarctic soils from collection pits of soils contaminated with crude oil were made. Basal saline medium (BSM) with the addition of petroleum crude and Diesel was used to select hydrocarbon degrading bacteria. Antarctic soil plates with the highest number of colonies and subantarctic soil plates were selected for cultivation in liquid medium at 10 ° C. In the liquid media with crude oil, the bacteria of antarctic origin showed the fastest growth.
Liquid cultures were subsequently inoculated into microcosms of subantarctic soils chronically contaminated with crude oil (E1 and E2) and commercial diesel (D). Preliminary, tests showed that the degradation reached 46 and 16% for E1 and E2 respectively, while the degradation for D exceeded 90% in 50 days.
Despite reaching the same degradation, the microcosms inoculated with bacteria showed a degradation kinetics superior. For the E1 soil, the bacteria isolated from the same soil showed the best performance. For the E2 soil, the set of Antarctic bacteria was the one that reached the maximum degradation in the shortest time (20 days).
These preliminary results show that the addition of Antarctic bacteria or isolated from the same soil can accelerate the biodegradation process, which presents an interesting potential to improve the recovery processes of contaminated soils in cold areas.

1316

Collecting Samples from Northern Islands in Antarctica for Bioprospecting Action

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Bioprospecting is a term that could be explained as "A research interest on plants and microorganism for producing large scaled pharmaceutics" first for scientists then industry. As a result of lack of resources from over-populated human wealth and global warming, it is in need to find new bio-catalyzers and other metabolites for large-scale industrial production. As a results, identification and revelation of potential production capacity of the extramophile organisms. For this kind of specific approach, phylogenic information and preliminary characterization is needed.

Two sampling methods were processed on site from Northern Islands in Antarctica, one sampling method is based on taking samples from the organisms avoiding serious damage to them; second sampling technique is to make 0.20/0.22 µm filtration on both fresh and marine water as 3 liters of sample to obtain eDNA. All sampled material were being stored in RNA/DNA Shield™ until DNA isolation date. Sampling route is started from King George Island (-62,18; -58,89) to Doumer Island (-64,87; -63,58) for all kind of material including water, soil and organisms.

DNA isolation is planned from all samples and DNA-sequencing will be performed in Oxford Nanopore™ Sequencer. For achieving the goal of gene hunting, obtained (consensus) sequence data will be processed on high-end cluster system. Resulting data is planned to be operated for identify organisms that could potencial to produce pharmaceutics. At collection points, GPS and meteorological data were also recorded for further analysis in order to create DNA based phylogenic network.

1463

Antibacterial activity of Antarctic's Lichen and Seaweeds against human and rainbow trout bacterial pathogens

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Lichens and seaweeds synthesize a great variety of chemically complex. Lichen (Usnea aurantiaco-atra) and seaweeds (Himantothallus grandifolius and Desmarestia confervoides) were collected in 23rd and 25th Peruvian Scientific Expedition from Antarctica, respectively, were transferred to Instituto Tecnologico de la Produccion (Callao-Peru) for processing. Samples were dried, grounded, and ultrasound-assisted extraction with acetone-methanol 1:10 (w/v) (lichen) and methanol 1:3 (w/v) (seaweeds) was performed. Methanol-acetone Extract (MAE) and Methanol Extract (ME) were obtained by vacuumed dried (30 °C).
The antibacterial activity of MAE against Staphylococcus aureus ATCC 14775, Pseudomonas aeruginosa ATCC 27853, Vibrio alginolyticus ATCC 17749, methicillin-resistant S. aureus (MRSA) and multidrug-resistant S. aureus; and MEs against Yersinia ruckeri biotype 1 and 2 from rainbow trout were evaluated by microdilution broth in 96-well plate. The minimum inhibitory concentration (MIC) and the inhibition of bacterial growth (IBG) were determined. Antibacterial activity of MAE was demonstrated against S. aureus (98.43% of IBG at MIC of 31.25 µg/mL), MRSA (98.76% of IBG at MIC of 250 µg/mL) and multidrug-resistant S. aureus (93.90% of IBG at MIC of 62.50 µg/mL). ME of H. grandifolius at MIC value of 96.00 mg/mL showed 98.50 and 98.80% of IBG against Y. ruckeri serotype 1 and 2, respectively and ME of D. confervoides at MIC value of 96.00 mg/mL showed 92.00 and 95.00% of IBG against Y. ruckeri 1 and 2, respectively.
It concluded that Antarctic's lichen and seaweeds present antibacterial property. Besides, U. aurantiaco-atra is a natural and potential source of antibacterial compounds against MRSA even multidrug-resistant S. aureus.

1222

Fungi-macroalgae associations in Potter Cove

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Aiming to study fungi-macroalgae associations in Potter Cove (25 de Mayo/King George Island, Southern Shetlands) 18 different species of macroalgae were sampled and screened for fungal growth. Fungal isolates (48) were recovered only from six macroalgae species (Gigartina skottsbergii, Palmaria decipiens, Neuroglossum delesseriae, Adenocystis utricularis, Ballia callitricha, Ascoseira mirabilis). These isolates were characterized considering their morphology and growth performance (colony diameter) on potato dextrose agar (PDA) at different temperatures (5 to 35°C). Only 12.5% of the isolates were able to grow at 35°C and, surprisingly, 18.75% were not able to grow at 5°C. All the isolates were able to grow at 15 and 25°C, while 75 % presented the largest colony diameter after 25 days at 25°C. Nevertheless, some isolates grew faster during the first incubation period at a temperature different from that where they showed the largest diameter at 25 days. This could be related to different metabolic adaptation to temperature that each isolate can put forth. After redundancy checking, 38 isolates were identified by molecular biology. Most of them belonged to Penicillium and Cladosporium genera, while others showed to be Cadophora, Antarctomyces, Mycochaetophora, and Pseudogymnoascus. No fungal growth was obtained from the other 12 macroalgae sampled, suggesting a possible antagonistic relation between some of them and the marine fungi in Potter Cove.

1707

The biological potential of Antarctic subsurface brines

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Groundwater systems, subglacial wetlands and hundreds of subglacial lakes exist below the ice sheets of Antarctica. These subice environments are proving to be diverse microbial habitats driven by unique geochemical and hydrological settings. In the McMurdo Dry Valleys of Antarctica, subsurface liquid exists as chemically diverse brines. Two locales where this brine leaks to the surface, enabling direct sampling, are features known as Blood Falls and Don Juan Pond. Extreme environments, such as these unique subglacial and sub-permafrost brines, are a potentially untapped resource for natural products such as enzymes, bioactive compounds or nano-structures with possible biotechnical applications. Here I will highlight recent molecular gene sequencing and cultivation data from these two unique brines, with a focus on intriguing physiological and genomic features of microbial isolates such as diverse pigmentation and gas vesicle production. In a sense, bioprospecting overlaps with research on elucidating the ecological function of natural communities. For example, persisters are a subpopulation of microbial cells that, in clinical settings, are transiently antibiotic tolerant or able to resume growth after a lethal stress exposure. In Antarctica, evidence of 'persistence' has been observed when dormant microbes are revived from ice cores 100s of thousands of years old or awaken from desiccated sediments. Understanding the ecological process of persistence borrows tools and insight from the clinical studies and vice versa. Thus, can exploring clinical applications and ecological understanding go hand-in-hand when studying Antarctic microbial isolates?

1099

Screening of soil yeasts with fermentative capacity from the Antarctic Continent for their application in the Chilean wine industry.

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The Antarctic Continent has become a crucial resource for the isolation of new microorganisms and secondary metabolites, given the competitive conditions of this environment and the high ultraviolet irradiation.
Considering this, we propose the search of new microorganisms for their use in the wine and beer industry. Considering the selective pressure of the Antarctic continent, we expect to discover new and diverse yeast species with the production of different secondary metabolites as a result of low fermentation temperature that will provide a distinctive set of aromas to the wine. We expect to generate conclusive results, which may contribute to an improvement of Chilean quality, by refining the production and variety of wines which will generate a high impact in this industry.
To achieve this objective, 6 soil samples collected in Fildes Bay, west of King George Island and 3 soil samples from the rhizosphere of Deschampsia antarctica Desv in King George Island, were processed for yeast isolation.
We obtained 125 yeasts from the soil samples, with a growth temperature of 10ºC. Overall, 25 yeasts (31%) have fermentative activity and are able to tolerate a culture medium with at least 20% glucose and up to 6% of ethanol.
The isolates were also characterized by optical microscopy assays and fingerprinting using PCR with arbitrary primers to discard identical strains.
The fermentative yeasts with high alcohol tolerance and fermentation at high concentrations of sugar will be used for micro-fermentation of synthetic must to determine their potential use in the production of Chilean wine.

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Whole genome hybrid assembly for comparative genomics to understand the adaptability traits of Antarctic bacteria

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Antarctic microorganisms might harbor unique features to survive in the extreme environment, which can be exploited for multiple biotechnological applications. However, bacterial adaptative mechanisms to the Antarctic polar region is not completely understood. In fact, reference genomes from Antarctic isolates are scarce on the databases, limiting the possibilities for comparative genomics studies. In this work, we applied a novel approach on whole genome sequencing to obtain reference genomes from bacterial Antarctic strains for comparative genomics analysis. Antarctic bacterial strains (x10) were sequence both by Illumina and Oxford Nanopore technologies. Low quality reads were filtered, and adapters were eliminated using Trimmomatic and NanoFilt/Porechop, respectively. Hybrid assembly was conducted with Unicycler and/or SPAdes and quality was assessed by Quast and CheckM. Pangenome analysis was performed with Roary or Pirate. The reference genomes were successfully assembled in one unique contig for all the strains. Preliminary comparative genomics analysis showed that Antarctic Streptomyces fildesensis devoted a higher percentage of its total genome for the biosynthesis of secondary metabolites. Genes associated with cold-adaptation were also identified in all the strains, including the exoribonuclease R, which is essential at low temperatures as part of the degradosome of some bacterial species. Other bacteria such as Sphingomonas alpina —non-previously reported in the Antarctic— showed unique metal and antibiotic resistance genes when compared to the other members of this genus. Our work highlights that ONT+Illumina hybrid assembly generated high-quality complete genomes, suitable for characterization of unique adaptative mechanisms and subsequent evolution studies on Antarctic bacteria.

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Multi-omics approach revealed culture and elicitation conditions of Antarctic bacteria for the production of antimicrobial compounds

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Concern about finding new antibiotics against drug-resistant pathogens is increasing every year. Antarctic bacteria have been proposed as an unexplored source of bioactive metabolites, however, most biosynthetic gene clusters (BGCs) producing secondary metabolites remain silent under common culture conditions. Our work aimed to characterize elicitation conditions for the production of antibacterial secondary metabolites from 34 Antarctic bacterial strains based on MS/MS metabolomics and genome mining approaches. Each bacterial strain was cultivated under nutrient and elicitation treatments, in a screening of 36 culture conditions, including the addition of lipopolysaccharide (LPS), sodium nitroprusside (SNP) and coculture. Metabolome were obtained by HPLC-QTOF-MS/MS and analyzed through molecular networking. Antibacterial activity was determined for each extract, and seven strains were selected for genome sequencing and analysis. Biosynthesis pathways were activated by all the elicitation treatments, which varies among strains and dependents of culture media. Increased antibacterial activity was observed for few strains and addition of LPS was related with inhibition of Gram-negative pathogens. Selected promising bacterial strains for drug discovery belongs to actinobacteria (Streptomyces fildesensis and Microbacterium sp.), proteobacteria (Sphingomonas alpina, Stenotrophomonas maltophilia and Massilia sp.), and firmicutes phyla (Bacillus subtilis). Antibiotic BGCs were found for all selected strains and the expression of Actinomycin, Carotenoids and Bacillibactin was characterized by comparison of genomic and metabolomic data. This work stablished the use of potential new elicitors for bioprospection of Antarctic bacteria and highlights the importance of new -omics comparatives approaches for drug discovery applied to this extreme and untapped environment.

1679

Diversity and bioprospecting of fungi present in impacted lakes of Fildes Peninsula, King George Island, Antarctica

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Antarctica has been subjected to global climatic changes over the last 50 years. Many of Antarctic environments are impacted by human activities by pollution problems, due to fuel, oil, waste contamination, and other activities associated with research stations and tourism. In this study, we characterized the diversity of fungi present in sediments samples of three lakes in Fildes Peninsula, King George Island, Antarctica under effect of anthropogenic activities. in addition, we evaluated the production of bioactive compounds by the resident fungi. We identified a fungal community composed by 63 taxa, which Cladosporium sp., Pseudeurotium hygrophilum, and Pseudogymnoascus verrucosus were the most abundant. A statistical comparison of hydrocarbon and heavy metals in sediment analysis demonstrated that the high concentrations of metals coincided with the lowest fungal diversity indices in Central Lake, and it may be influenced by human activities next to research stations, differently to those of the other two lakes, which were far from the stations. These results suggest that increasing anthropogenic activities in the Fildes Peninsula might be affecting microbial diversity and the fungal diversity may be a model to study the impact of human activities in Antarctica. In addition, the fungal isolates were evaluated about their biological activity against different clinical and agricultural pathogens. Among them, 40 fungal isolates demonstrated strong trypanocidal, herbicidal, and antifungal activities, and may represent cell factories for bioactive compounds to develop new drugs and less toxic herbicides.

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Isolation and identification of some microorganism species collected from Horseshoe Island, Skua Lake, Antarctica and microalgae cultivation

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The territory of Antarctica is the ideal place to study specific features of microorganisms that have not discovered yet. Despite significant progress in climatology, fisheries and biodiversity researches in the poles, a little is known about discovering the biological sources and ecological structure of the ocean surrounding Antarctica. Unique ecogeographic and climatological structure of the polar region have led to the microorganisms' adaptation to the region. In this study, some microorganisms were isolated from Horseshoe Island, Skua Lake-Antarctica, collected within the scope of 3rd Turkish Antarctic Expedition between January 25 and March 9, 2019, and identified as Chlorella variabilis (GenBank accession No:MN372092), Blastomonas sp. (GenBank accession No:MN384971) and Achromobacter sp. (GenBank accession No:MN396385). Isolated microalgae (Chlorella variabilis) were cultivated and characterized in the Algal Biotechnology and Bioprocess laboratory, Bioengineering Department of Yildiz Technical University. In this context, microalgae were cultivated in a lab-scale photobioreactor under moderate environment conditions. During cultivation, microalgae growth graph was obtained by spectrophotometric method and growth kinetics were calculated using these data to clear the effect of difference in cultivation conditions of algae. And also, biochemical characterization of microalgae was carried out after harvesting process by centrifugation. When the results of this study were examined, it was seen that isolated photosynthetic microorganisms can live in extreme pole conditions according to their strong adaptability. Besides, it was also determined that polar microalgae are highly rich in bioactive substance content.

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Investigation of antibacterial and antifungal effects of C. variabilis isolated from Horseshoe Island, Skua Lake-Antarctica

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Today, development of algal biotechnology and increasing its importance continues rapidly due to the recent trends and needs. Algae have been used in many different fields for many years due to their rich content of protein, fatty acids, vitamins, minerals etc. Many of these compounds have antimicrobial, antioxidant, antifungal, antiviral and anti-inflammatory properties and play an important role in preventing and treatment of diseases. When some types of microalgae are grown under various stress conditions such as low temperature and low light intensity, they can produce and accumulate substances with antimicrobial and antioxidant properties in the cell. The aim of this study is to investigate the antibacterial and antifungal effects of microalgae isolated from Horseshoe Island, Skua Lake, Antarctica. In this context, Chlorella variabilis (GenBank Accession number: MN372092), isolated from samples collected within the scope of the Turkish Antarctic Expedition-III, was cultivated in a photobioreactor, harvested and extracted. Antibacterial and antifungal effects of obtained extracts from polar microalga were investigated with antimicrobial activity tests by agar disc diffusion assay against bacteria (Escherichia coli ATCC 43888, Bacillus cereus ATCC 11778, Listeria monocytogenes ATCC 13932 and Salmonella typhimurium ATCC 14028) and fungi (Aspergillus brasiliensis ATCC 16404, Candida albicans ATCC 10231). The results of this study showed that the polar microalgal extracts have higher antibacterial and antifungal activities against some bacterial and fungal pathogens than microalgae isolated in moderate environment conditions.

1496

Low temperatures biosynthesis of photostable CdS quantum dots by UV-resistant psychrophilic bacteria isolated from Union Glacier, Antarctica.

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Fluorescent semiconductor nanocrystals (Quantum Dots, QDs) synthesized by living organisms have gained considerable interest during the last decade because of their unique properties. Extremophile microorganisms can biosynthesize QDs with improved properties such as salt and pH stability in the case of halophilic and acidophilic bacteria, respectively. A common problem of QDs is that constant UV-exposure induces photochemical reactions that affect their structure and stability. Thus, we hypothesized that UV-resistant psychrophilic bacteria from the Union Glacier, Antarctica, a glacier located about 1000 km from the South Pole, could biosynthesize QDs at low temperatures with increased tolerance to UV radiation. The Union Glacier presents high levels of UV radiation during the summer and temperatures below freezing throughout the year. These hyper-extreme conditions favor the development of unique psychrotolerant microorganisms with increased tolerance to UV-radiation. The aim of this study was to evaluate the photostability of CdS QDs produced at low temperatures by UV-resistant bacteria inhabiting the Union Glacier. UV-resistant psychrophilic bacteria were isolated from soil samples of two different sites at the Union Glacier. Three isolates capable of tolerating UV-C doses up to 100 J/m2 were obtained and identified as Paracoccus and Arthrobacter by 16s sequencing. Isolates were capable of biosynthesizing QDs at 4 and 20 °C with excellent optical properties (quantum yield, FWHM, band gap, size) and high photostability when compared with those produced by mesophilic bacteria (Escherichia coli). Finally, the QDs biosynthesized by UV-resistant bacteria showed decreased phototoxicity to E. coli cells when compared with those produced by mesophilic bacteria.

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Advanced biochemical and microbial diversity monitoring system based on micro/nano sensors and micro structure aerators , IoT compatible.

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There is a growing interest in the development of accurate, rapid and mobile methods of bioprospecting, but also for detecting pollutants responsible for contamination of waters with toxic substances. Biosensors are devices subject to continuous development as the detection of biomolecules in a real-time, label-free, highly sensitive and economical manner provides the basis of an attractive technology. We hereby propose acoustic IoT compatible sensors as means of detection and measurement of bioactive molecules.

Typically, a shear horizontal surface acoustic wave device (SH-SAW) consists of a piezoelectric substrate (ST-Z Quartz, Lithium tantalate LiTaO3 (360YX), lithium niobate LiNbO3 and Langasit) with a planar structure of interdigital electrodes transducers (IDT). The acoustic wave sensor uses the piezoelectric effect to electrically excite the acoustic wave at the input transducer (input IDT), which is then received at the output transducer (output IDT). Any biological material containing the analyte is put into contact with the piezoelectric material, that has on its surface a selective bioreceptor layer which can be added as required.

The mechanical and/or electrical interaction between the measurement analyte and the bioreceptor produces a change in the attenuation and/or in the propagation speed of the acoustic wave, which is then registered as the response of the sensor, IoT compatible and capable of transferring real-time measurements data to an online database.

1214

Characterization of fungi present in sulfide soils in Antarctica and their evaluation for studies in metal bioleaching processes

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We characterized the diversity of cultivable fungi present in sulfide soils located on the Keller Peninsula, King George Island, Antarctica and evaluate them for future studies of metal bioleaching. A total of 85 fungi were isolated and Mortierella amoeboidea, Mortierella globalpina, Mortierella turficola, Penicillium chrysogenum, Penicillium rubens, and Leucosporidium creatinivorum were the most abundant taxa. The fungi Hyaloscypha hepaticicola, Leptobacillium leptobactrum, M. turficola, P. chrysogenum, Penicillium rubens, Periconia prolifica, Pseudogymanoascus destructans, L. creatinivorum, Leucosporidium sp. and R. mucilaginosa were able to grow at pH 3 and also showed marked growth profiles for high temperatures up to 35 ºC and considered promising for future studies on the bioleaching of metals of interest. In the bioleaching test using a mining tailing complex, P. chrysogenum UFMGCB 17938 appears to have absorbed some metals of interest (Sr and Zn), but the bioleaching of Fe and Mn (metals most abundant in the tailings) was inconclusive. Finally, from the data sets obtained, acidophilic and mesophilic fungi present in the sulfide soils of Antarctica can be explored in the future with organisms capable of acting in processes of bioleaching of metals of interest in the mining industry.

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Conservation and characterisation of Polar Cyanobacteria by the BCCM/ULC collection

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The BCCM/ULC public collection funded by the Belgian Science Policy Office since 2011 aims to gather a representative portion of terrestrial, freshwater and marine cyanobacterial strains with a focus on the polar diversity with different ecological origins (limnetic mats, soil crusts, cryoconites, endoliths…). The collection's aim is to preserve the deposited biological material, to valorize it by performing research on it, to provide it to interested parties for fundamental and applied research, and to provide services linked to the identification of the Cyanobacteria for the scientific community. An ISO 9001 certificate was obtained for the public deposition and distribution of strains, as part of the multi-site certification for the BCCM consortium.

Currently, the ULC collection contains 253 cyanobacterial strains, with 134 being of Polar origin. Cyanobacteria in the Polar Regions represent key primary producers and are the main drivers of the food webs in a wide range of aquatic to terrestrial habitats. Due to their harsh environments, all these Polar Cyanobacteria may present interesting features to survive, for example, freeze/thaw cycles, fluctuating salt concentrations, high UV radiations, desiccation and other stresses. Morphological identification shows that the strains of BCCM/ULC belong to the orders Synechococcales, Oscillatoriales, Pleurocapsales, Chroococcidiopsidales and Nostocales. The 189 BCCM/ULC strains, for which 16S rRNA sequences were analyzed correspond to 69 OTUs (sequences with > 99 % 16S rRNA similarity), representing a large diversity

1546

The first report of microcystin producing Wilmottia murrayi from cryopreserved Antarctic cyanobacterial mats

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A new microcystin producing benthic cyanobacterium Wilmottia murrayi was isolated from a deep-frozen (-15^{o}C) sample collected from a cyanobacterial mat in a pond at Northern Victoria Land, Antarctica in 1985. Two strains successfully isolated from two different sites were characterised using both morphological and molecular approaches. Morphologically, the strains resemble Phormidium Kützing ex Gomont (1892). However, phylogenetic analyses using partial 16s rRNA sequences of the two strains showed that they formed a well-supported monophyletic clade with other Wilmottia murrayi and were well separated from Phormidium. Amplification of a fragment of the mcyE gene involved in microcystin biosynthesis from both Wilmottia murrayi strains confirmed the presence of this genetic determinant.This is a new report of microcystin synthesis from the cyanobacteria species Wilmottia murrayi both in Antarctica and worldwide.

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Heterocyclic compounds degradation using bacteria isolated from Antarctic soil

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Oil contamination in soil and seawater is undeniably a serious environmental concern with prolonged consequences towards the ecosystem. Oil contains heterocyclic compounds such as carbazole (CAR), dibenzothiophene (DBT) and dibenzofuran (DBF), are highly stable due to their planar ring structures, will reside in the environment for long periods unless treated effectively. The objective of this study is to isolate heterocyclic compounds degrading bacteria from the Antarctic environment for future development of bioremediation solution for cold environments. Enriched culture approach was chosen to isolate bacterial strains with ability to utilize CAR as sole carbon sources in minimal salt medium. The culture enrichment cycle were repeated at least 3 times at 15 ℃ using 100 rpm rotary shaker. As a result, a total of six strains were isolated after 2 months of shaking. The isolates showed CAR utilization at temperatures ranging from 5 ℃ to 35 ℃ with optimum growth between 15 to 20 ℃. Analyses of residual CAR using GC showed complete substrate utilization after 9 days. Utilization of DBT, DBF, biphenyl, fluorene and phenanthrene were also confirmed by agar media growth. These results indicated that these isolates posses wide range substrate utilization ability. Further studies on these strains will lead to more understanding for application of bioremediation in the future.

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Heterocyclic compounds degradation using bacteria isolated from Antarctic soil

Seiryu Take[1], Tatsuya Niwano[1], Siti Aqlima Ahmad[2], Peter Convey[3], Claudio Gomez-Fuentes[4], Azham Zulkharnain[1]

[1]Shibaura Institute of Technology, Saitama, Japan, [2]Universiti Putra Malaysia, Serdang, Malaysia, [3]British Antarctic Survey, Cambridge, United Kingdom, [4]Universidad de Magallanes, Punta Arenas, Chile

Oil contamination in soil and seawater is undeniably a serious environmental concern with prolonged consequences towards the ecosystem. Oil contains heterocyclic compounds such as carbazole (CAR), dibenzothiophene (DBT) and dibenzofuran (DBF), are highly stable due to their planar ring structures, will reside in the environment for long periods unless treated effectively. The objective of this study is to isolate heterocyclic compounds degrading bacteria from the Antarctic environment for future development of bioremediation solution for cold environments. Enriched culture approach was chosen to isolate bacterial strains with ability to utilize CAR as sole carbon sources in minimal salt medium. The culture enrichment cycle were repeated at least 3 times at 15 ℃ using 100 rpm rotary shaker. As a result, a total of six strains were isolated after 2 months of shaking. The isolates showed CAR utilization at temperatures ranging from 5 ℃ to 35 ℃ with optimum growth between 15 to 20 ℃. Analyses of residual CAR using GC showed complete substrate utilization after 9 days. Utilization of DBT, DBF, biphenyl, fluorene and phenanthrene were also confirmed by agar media growth. These results indicated that these isolates posses wide range substrate utilization ability. Further studies on these strains will lead to more understanding for application of bioremediation in the future.

SCAR 2020

Antarctic Science - Global Connections

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SESSION 25

SEA ICE IN THE ATMOSPHERE-ICE-OCEAN-BIOSPHERE SYSTEM: HOW, WHERE AND WHY IS IT CHANGING, AND WHAT ARE THE EFFECTS?

Petra Heil

Klaus Meiners, Rob Massom, Pat Wongpan

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Seasonal and interannual variability of landfast sea ice in Atka Bay, Weddell Sea, Antarctica

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Landfast sea ice attached to the Antarctic coast is a critical element of the local physical and ecological systems. Through its direct coupling with the atmosphere and ocean, fast ice and its snow cover are also a potential indicator of processes related to climate change. Since 2010, a monitoring program that is part of the Antarctic Fast Ice Network (AFIN) has been conducted on the seasonal fast ice of Atka Bay, located on the northern edge of Ekström Ice Shelf in the eastern Weddell Sea.
Here, we show results of regularly measured snow depth, freeboard, sea-ice- and sub-ice platelet layer thickness across the bay, combining them with observations from the meteorological observatory at Neumayer Station, as well as satellite images. On average, the annual fast-ice thickness at the end of the growth season is about 2 m, with a platelet layer thickness of 4 m beneath. Due to the substantial snow accumulation on the sea ice, a characteristic feature is frequent negative freeboard, and associated flooding of the snow/ice interface. Strong easterly winds in the area govern the year-round snow redistribution and also trigger the breakup events of the bay during summer months.
Since there is no obvious trend in any of the observed variables, neither in the present 9-year observation period, nor in comparison to studies from the 1980 and 90s, our monitoring efforts provide an important baseline for an Antarctic fast-ice system that will likely undergo drastic changes in the future, as already projected by climate modelling studies.

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Large Scale Biophysical Characterization of Antarctic Under-Ice Environments

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Sea ice is a highly heterogeneous habitat varying on scales from millimeters to kilometers. The spatial variability of physical properties dictates the variability of sea ice microbial communities and of sympagic fauna. Characterizing the biophysical environment at the sea ice-water interface at scales of meters to kilometers still faces logistical hurdles. In this study, we present under-ice data collected with a Surface and Under-Ice Trawl (SUIT) during three campaigns between 2013 and 2018 covering the seasons of winter and summer in the Weddell Sea. The SUIT is equipped with a sensors array from which we retrieve several environmental properties, including sea-ice thickness, spectral radiation and algal chlorophyll a concentration in the ice (in-ice chl a). With an average trawl distance of about 2 km, the SUIT covers scales that can rarely be sampled with classic methodologies. The present work, thus, represents the first multi-seasonal habitat characterization based on kilometer-scale profiles. The present data highlight regional and seasonal patterns in water properties. Antarctic sea ice thickness and snow depth remain quite uniform between seasons, and thickness distribution agrees well with data collected over larger scale with an EM-bird. Light transmission, however, is low in winter. Despite the thick snow depth, the overall under-ice light is considerable during Antarctic summer. In-ice chl a exceeds 7 mg chl a m−2 during Antarctic winter, when water chl a concentrations remains below 1.5 mg chl a m−2 , thus providing a potential food source for overwintering of sympagic and pelagic fauna.

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Hyperspectral imaging of sea-ice cores to map the microspatial variability of its biophysical properties

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Within the sea-ice biome, sea-ice algae constitute a large, yet poorly quantified fraction of biomass contributing to polar marine productivity and large-scale biogeochemical cycles. Albeit, the analyses of large-scale ecological patterns warrant for the integration of small-scale processes and the microspatial variability of ice algal biomass has remained mostly uncaptured and unquantified. To address this knowledge gap we present a field-deployable hyperspectral scanning set-up that can map both the vertical and horizontal chlorophyll-a proxies in sea-ice cores at sub-mm resolution. The set-up uses artificial light transmitted through horizontal sections of ice cores to enable the assessment of spectral indices against extracted chlorophyll-a. We developed new spectral indices which explain 85 % of variation in sampled chlorophyll-a for our study area. Indices were statistically validated and evaluated against traditional methods. Following a tailored image pre-processing workflow we present a regression model developed for both in situ and ice-core hyperspectral images. While validation remains a challenge under current sampling regimes, this preliminary result highlights the possibility to map chl-a in mg m2 at a mm-scale on a per-pixel basis. This methodology sheds light onto undocumented yet dominant features of the under-ice habitat.

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The internal structure of East Antarctic pack ice in summer and its physical implications

Matthew Corkill[1], Alexander Fraser[1], Petra Heil[2,1], Eva Cougnon[3], Cristina Genovese[1], Julie Janssens[4], Noriaki Kimura[5], Sebastien Moreau[6], Delphine Lannuzel[1]

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Antarctic sea-ice extent retreats to its annual minimum of about 3 million km² between late February and early March at which time most of the remaining ice is thick, free-drifting pack ice. These thick floes have already delivered nutrients for an early spring phytoplankton bloom via an extensive brine network that develops within the sea ice as the ice temperature increases. In late summer, snow loading becomes sufficient to depress the ice freeboard and refill the brine network with nutrient-replete seawater to sustain ice-algal growth. Few studies have focussed on what happens within pack ice between these two periods of algal growth. Here we show that between Wilkes and George V Lands (East Antarctica) around mid-summer 2016-17, pack ice was rotten and highly permeable, but that full-depth percolation was limited by impermeable superimposed ice layers and brine stratification. Despite insufficient snow loading to introduce surface flooding and/or upward brine flushing, permeable submerged layers allowed lateral intrusion of seawater and subsequent downward percolation. We conclude that these permeable subsurface layers were likely caused by historical ice floe rafting and glacial melt sourced ice crystal deposition, processes which are also likely responsible for growing the floes thick enough to persist through the summer. The mid-summer seawater incursions identified here present a mechanism for replenishing nutrients and allowing ice algal growth at an under-sampled time of year in an under-sampled region.

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Direct and indirect contributions of ice shelves to micronutrient supply to the surface waters around Antarctica

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Previous studies showed that satellite-derived estimates of chlorophyll in coastal polynyas over the Antarctic continental shelf are correlated with the basal melt rate of adjacent ice shelves. We use a 5 km resolution ocean/sea ice/ice shelf model of the Southern Ocean to examine mechanisms that supply the limiting micronutrient iron to Antarctic continental shelf surface waters. Four sources of dissolved iron are simulated with independent tracers, assumptions about the end member concentrations, and an idealized summer biological uptake. Direct injection of iron from melting ice shelves is important to the total dissolved iron supply to surface waters, providing about 6%. However, the contribution from deep sources of iron on the shelf is much larger at 71%. The relative contribution of dissolved iron supply from basal melt driven overturning circulation within ice shelf cavities is heterogeneous around Antarctica, but at some locations, such as the Amundsen Sea, it is the primary mechanism for transporting deep dissolved iron to the surface. Correlations between satellite chlorophyll in coastal polynyas around Antarctica and simulated dissolved iron suggest that productivity of the polynyas is linked to the basal melt of adjacent ice shelves. This correlation is the result of upward advection or mixing of iron-rich deep waters due to circulation changes driven by ice shelf melt, rather than a direct influence of iron released from melting ice shelves. The effect of possible changes in the winds on iron supply is expected to be heterogeneous around Antarctica and this is explored with the model.

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Understanding future changes in sea ice dynamics in the Southern Ocean on net community production of food: Results from a large data set synthesis

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Modeling suggests the response of Antarctic sea ice extent, seasonality, and thickness to future climate change will be complex, yet averaged over large areas sea ice is expected to be thinner, less extensive, form later, and melt earlier. These characteristics influence net productivity and phytoplankton community composition in the Southern Ocean. We assembled a large data set on sea ice and sea ice melt conditions, water column TCO2 deficits, [oxygen], particulate organic C standing stock and chlorophyll concentrations, surface water pCO2, and hydrographic data (temperature, salinity, mixed layer depth, water column stratification). We use data sets from 8 cruises spanning 22 years (NBP cruises 96-06, 97-09, 98-07, 01-01, 06-01, 06-08, 13-02, and 18-01) where the measurements were made by the same labs. Cruise tracks span the Bellingshausen Sea to the Ross Sea and on to the Edward VIII Gulf. We stratified estimates of net community productivity (NCP) according to the following regimes: >80% sea ice cover, <20% sea ice cover, sea ice edge melt water bloom, early/late season well-mixed water column, and mid-summer well-mixed water column. Significant differences exist in rates and extents of instantaneous and net seasonal primary production and estimated C export among these different regimes. Depth integrated NCP rates are highest in shallow mixed layers associated with melting sea ice as well as in open water Phaeocystis blooms in late Spring/early Summer. Our findings can be used with sea ice model projections to estimate future climate change impacts on Antarctic food webs.

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Wind-driven sea ice drift analysis in the Western Ross Sea, Antarctica, based on high-resolution satellite observation and modelled surface wind

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Sea ice drift is forced by winds and ocean currents and is an essential element in the dynamics of polar oceans. Sea ice extent, concentration, and thickness are heavily influenced by ice dynamics. For the accurate representation of sea ice in climate models, realistic parameterization of the sea ice motion and deformation rates are crucial. Here we present high-resolution sea ice deformation fields of the Western Ross Sea as a basis to explore ice-atmosphere interactions and influence of wind on sea ice drift over a short time scale. The study region includes the three main polynya areas (Ross Ice Shelf, McMurdo Sound, Terra Nova Bay) which experienced a significant increase in sea ice extent over the satellite observation period, and wind forcing is possibly the main driver of this change. Focusing on months with maximum sea ice extent (April – October) between 2002-2012, we used sequential high-resolution Advanced Synthetic Aperture Radar (ASAR) Envisat images in wide swath mode at 150m pixel resolution. Pattern-matching techniques were used to find the motion vectors, which are correlated to 3-hourly AMPS wind velocity data at a spatial resolution of 5 km. Here we present the long-term correlation results between sea ice drift velocity and wind velocity. Our study shows that the sea ice motion is strongly linked to the strong geostrophic winds, but due to the extremely variable wind patterns, a high temporal resolution (2-4 per day) of image acquisitions in key sea ice formation areas is essential.

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Production of iron-binding ligands in summer sea-ice

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East Antarctic land fast and pack ice cores were sampled during mid-summer (December 2016 – January 2017) for both physical and biogeochemical characterization. Temperature and salinity data indicated warm and highly permeable sea ice at this time of year. Chlorophyll-a maxima were found in bottom ice in fast ice stations (up to 127.5 µgL-1), and at intermediate depths in pack ice stations. Nevertheless, the overall low Chlorophyll-a and high particulate organic carbon concentrations found across all stations in summer sea ice, compared to earlier season ice surveys, suggest a highly heterotrophic biomass. This result is supported by nutrient stress, with NOx depletion (<0.2 µM) and a NH4+/NO3- ratio about 10 times higher than during springtime; by an average POC/PON ratio of 11.3 ± 4.2; and by concentrations of particulate exopolymeric substance (EPS) up to 16,290 µg xeq L-1.

Fast ice shows dissolved iron (DFe) concentrations (up to 20 nM) twice as high as those found in pack ice (0-10 nM). Regardless of the ice type, DFe was >99% organically complexed, with the organic ligands concentration always exceeding the DFe concentration. The conditional stability constant (logk'FeL = 12.4 ± 0.3) suggests that dissolved EPS represent the main type of Fe-binding ligands in summer sea ice. We are suggesting that bacteria in summer sea ice contribute to remineralization of organic matter and production of Fe-binding EPS, which help retain Fe in the system, therefore likely extending the fertilization potential of sea ice.

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Introduction of the Ice Algae Model Intercomparison Project phase 2 (IAMIP2)

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Ice algae play a fundamental role in shaping polar marine ecosystems and biogeochemistry. While this claim is supported by field observations, their influence at the regional and global scales remains unclear due to limited spatial and temporal coverage of observations. To address this knowledge gap, we introduce a new model intercomparison project (MIP), referred to here as the Ice Algae Model Intercomparison Project phase 2 (IAMIP2). IAMIP2 is built upon the experience from the previous MIP, and expands its scope into global covering both Arctic and Antarctic, and centennial spanning from the mid-twentieth century to the end of the twenty-first century. Participating models are three-dimensional regional and global coupled sea ice-ocean models that incorporate sea-ice ecosystem components. These models are driven by the same initial conditions and atmospheric forcing dataset by incorporating the protocols of the Ocean Model Intercomparison Project, an endorsed MIP of the Coupled Model Intercomparison Project phase 6 (CMIP6). Doing so provides more robust estimates of model bias and uncertainty, and consequently advance the science of polar marine ecosystems and biogeochemistry. A diagnostic protocol is designed to enhance the reusability of the model data products of IAMIP2. Lastly, the limitations and strengths of IAMIP2 are discussed considering prospective research outcome.

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Nutrient biogeochemistry in Antarctic land-fast sea ice and exchange with the surface ocean

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Sea ice is an important component of the Antarctic marine system due to its strong coupling with upper ocean processes, its exchanges with underlying seawater and the overlying atmosphere, and its ability to support life. The biogeochemical cycling of nutrients in sea ice and exchange of dissolved and particulate constituents with the surface ocean are particularly important in regulating primary production by ice algae, organic matter remineralisation within the ice matrix, and potentially seeding of phytoplankton blooms. We have produced an international compilation of nutrient concentration data from land-fast sea ice around the Antarctic continent. We will present and discuss these data with a view to describing the overall trends observed at the circum-Antarctic scale, and the differences in these trends between regions and over seasonal and interannual timescales. Our results highlight the importance of exchange with surface waters in supplying nutrients to the sea-ice matrix, and of ice thickness in regulating the availability of light to ice-algal communities concentrated close to the ice-ocean interface and therefore the degree of nutrient uptake. Our data further show strong seasonality in the nutrient content of the ice column, as well as a decoupling of the biogeochemical cycles of nitrogen, phosphorous and silicon. This international circum-Antarctic dataset will be useful in informing modelling efforts focusing on the role of sea ice in modulating Southern Ocean biogeochemistry and its importance in the Earth System.

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The spatio-temporal patterns of landfast ice in Antarctica during 2006-2011 and 2016-2017 using high-resolution SAR imagery

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Landfast ice is an important component of the Antarctic sea ice regime. It affects the Antarctic climate and ecological system. In this study, the first high-resolution, long time series of the landfast ice edge from 2006 to 2011 and 2016 to 2017 is presented. The dataset was produced based on the improved net gradient difference algorithm using 2470 SAR scenes from ENVISAT and Sentinel-1A/B as well as manual analysis of MODIS imagery to fill in SAR data gaps. The study results show that the landfast ice area in November for all studied years was approximately 49.49±3.25 ×104 km2, accounting for about 3%~ 4% of the total Antarctic sea ice area. The maximum area was 55.70×104 km2 in November 2007, compared to the minimum area 44.01×104 km2 in 2011.The area in West Antarctica was about 40% of that in East Antarctica. The distribution of landfast ice in Antarctica has significant regional differences. The extent in the Indian Ocean sector is the maximum with a mean value of 16.49±1.1 ×104 km2; however, the ratio of the landfast ice area to the sea ice area in the Pacific Ocean sector is the highest. Twenty-four landfast ice zones with groups of small, grounded icebergs were identified, most of which were located in East Antarctica, particularly along the Wilkes Land and Oates Land. Two cases are presented to illustrate how giant, grounded icebergs affected landfast ice. Results from this study are well suited to underpin the Antarctic climate or ecological system studies.

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Unprecedented phytoplankton blooms in the Maud Rise polynya, Lazarev Sea

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Anomalously record lowest sea-ice extent and area observed since 2016 to 2019 with the maximum melting occurred in 2017, corresponding to the upper ocean warming of the Southern Ocean. A large polynya on the Maud Rise reappeared during austral winter-spring 2017 since its appearance in 1970s. Satellite derived chlorophyll-a concentration in the polynya showed unprecedented phytoplankton blooms with chlorophyll-a reached up to 4.67 mg m-3. Multi-satellite data indicated that the bloom appeared for the first time in the entire mission records started since 1978. Argo float located in the polynya provided evidence of bloom condition in austral spring 2017 (chlorophyll-a up to 5.47 mg m-3) compared to the preceding years of prevailed low chlorophyll-a. The net primary production from Aqua-MODIS chlorophyll-based algorithm showed that the Maud Rise polynya was as productive as the Antarctic coastal polynyas with the carbon fixation rates reached up to 415.08 mg C m-2 day-1. The performances of ocean-color based models were evaluated by comparing with the in-situ NPP estimated using 13C tracer during the Indian scientific expedition to the Southern Ocean.

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Airborne measurements of land-fast sea ice thickness in the SW Ross Sea

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The Victoria Land coast is fringed by land-fast sea ice that interacts with ice shelves and floating ice streams, resulting in the presence of a sub-ice platelet layer as an indicator of supercooled ice shelf meltwater at the ocean surface. Airborne electromagnetic induction (AEM) sounding characterises the thickness of sea ice and its sub-ice platelet layer. AEM surveys have been conducted over the spring fast ice of McMurdo Sound on five years between 2009 and 2017. The ice was mostly level and more than 2 m thick. It was underlain by a sub-ice platelet layer, with maximum thickness of more than 6 m near the ice shelf edge. The sub-ice platelet layer thickness distribution was in good agreement with in-situ measurements and was remarkably similar from year to year, suggesting weak interannual variability in the ocean circulation. In November 2017 the AEM survey extended along the coast of Victoria Land. Fast ice between Terra Nova Bay and the Adare Peninsula was more than 2 m thick and heavily deformed by onshore pack ice drift. A sub-ice platelet layer, up to 2.5 m thick, was observed in front of the Hell's Gate Ice Shelf beneath 2 m of level sea ice. We use our knowledge of ice shelf outflow in McMurdo Sound to draw conclusions regarding fast ice adjacent to less accessible features of the Victoria Land coast. Our results have important implications for understanding ice shelf melt and the role of the fast ice/platelet ice in biological productivity.

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Was 2016 an atypical year for the carbonate system in the Gerlache Strait, Antarctica?

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Polar coastal regions are highly dynamic regions with large spatial changes mainly related to sea ice distribution and meteoric water. Moreover, ENSO conditions can considerably influence the input of water masses onto continental shelves along the Antarctic coast. The Antarctic Peninsula has been affected by climate change factors, e.g., ocean warming, freshening, and changes in sea ice extent, periodicity, and thickness. These changes also affect the polar biological community all through the food web. Therefore, it is important to well constrain the parameters of the carbonate system for a good determination of its variabilities and improvement of numerical models. This work investigates the local processes affecting the spatial distribution of carbonate system parameters in the Gerlache Strait waters during the austral summer of 2016. Data from NAUTILUS (2015-2018) were used to analyse the spatial distribution of carbonate system parameters. Results show a high dissolved oxygen (>300 µmol/kg) and low carbon (<2150 µmol/kg) pools in the strait, which is not observed in any other NAUTILUS year. This reflects into an aragonite saturation state >1.5. Results suggest a combined action of sea-ice meltwater arriving from the Bellingshausen region and local glacial meltwater discharge. The period of 2015-2016 was determined by El Niño conditions, which impacts the periodicity of sea ice over the Bellingshausen Sea continental shelf, thus, reflecting the low salinity observed in 2016. This combined event was probably responsible for the low oxygen pool observed in the strait, which is linked to a high biologically productive event in the same year.

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Spatial distribution of chlorophyll-a in the Bransfield Strait and its relationship with glacier coverage during the southern summer 2018

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Chlorophyll-a being the major component of photosynthetic organisms allows to determine the trophic state of marine ecosystems and is also an indicator of primary marine productivity. The goal of this research was to estimate the spatial distribution of the chlorophyll-a concentration during the southern summer in the Bransfield Strait (-60.16° and -63.04° South; 55.63° and -62.17° West) and its relationship with glacier coverage. We processed the four-band algorithm (OC4) of Landsat 8 OLI sensor satellite images to obtain the chlorophyll-a values satellite. These values were correlated with in situ data obtained from the collection of 45 samples of sea surface along the Strait. The results show that the surrounding glacier areas were related to chlorophyll-a concentrations. The analysis of in situ and satellite data has a correlation coefficient of 0.95 with an average chlorophyll-a variation of ~ 0.19 mg/m3. Also, a higher concentration of chlorophyll-a is observed in areas with less glacier coverage (King George Island and Elephant Island) with values of 1.11 mg/m3; while in areas influenced by cold currents from the Antarctic Peninsula the concentration is lower (0.06 mg/m3).

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Influence of the glacial contribution (sediments - fresh water) on marine nutrients of the Bransfield Strait during the austral summer 2018

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Antarctic glaciers are complex and dynamic systems that provide fresh water and sediments to the ocean, this constitutes an inorganic source of nitrogen and phosphorus for photosynthetic organisms. The goal of this research was to estimate the spatial distribution of marine nutrients during the southern summer in the Bransfield Strait (-60.2° and -63.0° South; 55.63° and -62.17° West). There were analyzed phosphates, silicates, nitrites and nitrates concentrations of 44 surface seawater samples along the Strait. The glacier coverage was obtained from the supervised classification of Landsat 8 images. To estimate the spatial distribution of nutrients and their relation to glacier coverage, the kriging method was applied.
The results show that the concentration of nutrients varies inversely to the proximity of the sediment feathers from glaciers. In the coasts a lower concentration is observed due to the reactivation of algae and microorganisms, released by the glacial contribution, that use the nutrients for their reproduction (greater chlorophyll-a, up to 1.03 µg/L).

The Antarctic Peninsula coasts that have more glacier coverage and low sediment feathers have a higher concentration of nutrients (1.44 phosphates; 60.69 silicates; 0.24 nitrites; 13.35 nitrates µM) compared to South Shetland Islands. The Elephant Island is located in the northwest in the open sea has a greater accumulation of nutrients in their surroundings (1.61 µM phosphates).

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Characterisation of under-ice habitats in the Weddell Sea pack-ice zone during summer

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Sea ice plays a key role in Southern Ocean physics and biogeochemical cycles, and is a major driver of Antarctic marine ecosystem processes. Importantly, sea ice provides a substrate for ice algae which serve as food source for pelagic herbivores, e.g., Antarctic krill (Euphausia superba). The under-ice environment also provides a spatially complex refuge from predators. Coincident measurements of sea-ice parameters and krill under the sea ice are critical to understand the habitat utilisation of this Antarctic key species.
During a summer voyage to the Weddell Sea we combined classical ice coring methods with the deployment of novel instrumented under-ice observing platforms to collect concomitant measurements of ice algal biomass and the abundance of Antarctic krill at sea ice - water interfaces, under different types sea ice. Particularly, we deployed horizontally profiling platforms (Remotely Operated Vehicle (ROV) and Surface and Under Ice Trawl (SUIT)) to measure ice algal biomass and krill abundance along 100-1000m long transects. Algal biomass was estimated from under-ice irradiance data, cross-calibrated with point measurement from ice cores. Krill abundance was determined from SUIT catches and from images of the ice-water interface taken with an up-ward looking camera mounted to the ROV. Our data show high small-scale spatial variability in both ice algal biomass and krill abundance. First analyses indicate that the Weddell Sea marginal ice zone, particularly areas with a high amount of brash ice, harbour high ice algal standing stocks with associated high abundances of krill dwelling directly at the sea-ice water interface during summer.

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The functional role of marginal sea ice in trace metal dynamics in the Southern Ocean

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Samples were collected during the austral winter and early spring of 2019 to better understand the partitioning and seasonal cycling of bioactive trace metals and their effect on ocean biogeochemistry in the Antarctic marginal sea ice zone (MIZ) (57ºS-59ºS:0ºE-25ºE). Trace metals (TM), nutrients, Chl a and pigments were analyzed in wet and dry aerosols, snow, sea ice, and underlying water column. The preliminary results show the TM concentration in the ice cores were higher than the underlying seawater column and the overlying snow layers. Within the ice cores, the metals showed a boomerang-shaped profile with a top and bottom maxima and intermediate minima. The profiles mimic the salinity profiles. Chl a, a proxy for phytoplankton growth, was consistently observed in the ice cores, especially in the early spring, with higher concentrations associated with high TM content in the ice. We believe that the formation of marginal ice during winter not only prevents the exchange of trace metals (TM) between the atmosphere and sea, it also partitions dissolved TM within the ice phase. During spring and summer melting; however, MIZ acts as a source of bio-limiting metals to the adjacent seawaters that are known to cause phytoplankton blooms. It is estimated that 15% of yearly net primary production in the Southern Ocean (Taylor et al., 2013) occurs in MIZ.

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Hot spot next to ice: an unusual haven for krill reproduction

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Conventional Antarctic biology dictates that adult krill offshore move in to the slope and shelf break in summer, where they spawn. Shallow waters near to the ice shelf and adjacent sea-ice are not the typically cited locations for krill reproduction. Here we report substantial occurrences of larval krill in waters next to ice shelf and iceberg-embedded sea ice in the Amundsen Sea from our sampling, mostly a mesh filtration of near-surface sea water supplied to on-board laboratories. Such larval concentrations were accompanied by unique acoustic signals and there was an obvious spatial variability that favors particular types of habitat. Surface water temperature tended to be low, being close to either ice shelf or sea ice. Reasonable supply of diatoms to fuel krill reproduction existed in the water column, even when there was a Phaeocystis bloom developed nearby, which often essentially displaces diatoms. The localities of high larval density were rather shallow, sometimes with distinct topography, less than 500 meters in depth, beyond the reach of Circumpolar Deep Water, known to facilitate the hatching of krill eggs. This is contrary to traditionally known krill spawning locations as deep as 1000 meters. Krill furcilia were found mostly where thick sea ice was present, and hardly ever in open waters close to glaciers. Where the parent population comes from, where these young krill a long way from Antarctic Circumpolar Current will end up and whether they will join the mainstream of circumpolar krill population remain as intriguing questions.

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Ice algal phenology in a changing cryosphere

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The Arctic decline in the past decades is being well reproduced by CMIP5 and CMIP6 models (Tedesco et al 2019; Tedesco et al In preparation). In contrast, CMIP6 models largely underestimate the Antarctic sea-ice extent trend for all months (Vichi et al In preparation). Also, while the decline of Artic sea ice is being undergoing largely on a pan-Arctic scale (Tedesco et al In preparation), we will show that regional and seasonal differences in the Southern Ocean are often represented by models in a opposite way (Vichi et al In preparation).

Recent studies (Tedesco et al 2019) combining sea-ice biogeochemical modelling with CMIP5 models presents future scenarios of largely altered Arctic ice algal primary production and phenology. The expected increase in production turns limited by the diminished seasonal areas, while blooms in areas with expanding first-year ice become limited by narrow growth windows. Disruption of the seasonality of the algal blooms have already created mismatches for the timing of zooplankton production, which in turn may lead to the possibility of phenological uncoupling with secondary and tertiary consumers.

The large disagreement between model simulations and satellite observations of Antarctic sea-ice extent trends raises the fundamental question whether CMIP6 models can be used for hindcasts and projections of ice algae dynamics as done for the Arctic. While an understanding of the discrepancies is a fundamental step forward, climate models remain the only available tools to quantitatively assess long-term changes in sea-ice biogeochemical dynamics also in the Southern Ocean.

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3D imaging of ocean surface in the Antarctic marginal ice zone: Surface waves dynamics and interaction with sea ice

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We report simultaneous underway measurements of pancake ice properties and ocean wave characteristics from a winter expedition to the Antarctic marginal ice zone aboard the S.A. Agulhas-II. Observations were gathered with a stereo camera system, which allows the reconstruction of the 3D ocean surface. Focus is given to properties of intense waves-in-ice propagating through a 100% sea-ice cover comprised of pancakes floes (60%) and interstitial frazil ice (40%) during an explosive polar cyclone crossing the Antarctic marginal ice zone. Results show propagation of ocean waves into the sea ice up to approximately 100 km from its edge, spectral changes and concurrent energy attenuation as well as properties of individual waves, including the highest waves (height of 8.5 m) ever recorded this far into the marginal ice zone. Measurements underscore low wave dissipation in pancake ice, and a spectral evolution towards longer periods due to the differential attenuation of the spectral wave components. The directional energy spreading narrows at the edge and subsequently broadens deeper into the marginal ice zone.

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Crucial role of Antarctic virioplankton in organic primary aerosol production

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During the winter season, sea-ice is a refuge of Antarctic microbial communities including phytoplankton, heterotrophic protists, bacteria and viruses. Then, along summer, due to sea ice melting, those microorganisms are released to the water and their metabolism and trophic interactions play a key role in the biogeochemical cycles in the ocean. Viral infections on microorganisms produce large quantities of dissolved and particulate organic matter (OM) including cell debris and other colloidal material. This OM may be incorporated in bubble-mediated spray production forming cooling marine aerosols and cloud layers potentially affecting climate. We therefore, tested experimentally the effect of viral lysis on bacteria, heterotrophic protists and phytoplankton, and their contribution to the production of aerosol precursors compounds during a field study carried out near the Antarctic peninsula in February 2019 using fixed and mobile platforms. We performed four experiments on melted sea ice incubated for 48-72 h in 60 L mesocosm (using two treatments: unamended natural viruses and viral addition) and subjected to still and bubbled periods. The generated aerosols were monitored by on-line and off-line aerosol techniques.
Our results - systematically for all four experiments - showed that after viral addition the microbial mortality (rate of lysed cells/mL/ d) increased. Concurrently, the released organic C, N, P augmented and significantly correlate with the concentration of dissolved organic carbon measured in the sea ice samples. We discuss that our data support the crucial role of virus mediated lysis of microbes on sea-ice-ocean-atmosphere interactions, including aerosol particle production.

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Phytoplankton phenology is driven by sea ice seasonality in climate simulations of the Southern Ocean

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Earth system models from the Climate Model Intercomparison Project are strongly biased in Southern Ocean phytoplankton phenology, especially along the ice edge where production is larger. In this study we describe the mechanisms driving CMIP models to misrepresent seasonal primary production in the Atlantic marginal ice zone during late winter. We link subsurface light availability during this period to simulated early growth, arguing that a combination of ice cover and deeper winter mixing prevent biomass accumulation in the real ocean, while in models this combination of factors is not present. Furthermore, we find a statistically significant correlation across the CMIP5 model ensemble between vertical stratification and the location of the ice edge; whereby the more equatorward the ice edge is, the closer to the surface stratification occurs. This relationship is also evident in CMIP6 models. We argue that models may be grouped according to how strongly they express two major controls on their phenology, namely, the location of the ice edge and the degree of stratification present in the water column in late winter. We find that models with small biases in just one of these controls (but large biases in the other) are able to simulate bloom initiation close to observations, while models with significant biases in both controls initiate growth 2–4 months early.

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In-situ measurements of sea ice drift and response to ocean waves

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Sea ice dynamics are intrinsically coupled to the forces of wind, currents and waves. Prediction of sea ice drift, break-up and, consequently, sea ice extent requires a comprehensive understanding of the response of sea ice to the environment. Such understanding is, however, strongly restricted by the limited observations available in this harsh climate. In December 2019, we deployed four instruments on landfast Antarctic sea ice (69°S 76°E) a few kilometers apart to measure sea ice vertical motion, as a response to ocean waves, and sea ice drift. The instruments include two Sofar Spotter wave buoys and two low-cost open-source ice motion loggers. Nearly one month after deployment the instruments started moving after a large ice floe of approximately 15 by 20 km broke off, possibly triggered by an energetic swell event from the Southern Ocean. The instruments separated after disintegration of the large ice floe. At the end of the deployment, a Southern Ocean storm produced swell in excess of 4 m near the continent, leading to wave heights of up to 60 cm in the sea ice cover. This event was closely followed by a different low pressure system passing over the site with winds of up to 15 m/s, with instruments measuring waves of up to 2 m height. The rapid changes of the sea ice cover and energetic response to ocean waves originating from the Southern Ocean emphasises the need of continuous observations of waves and sea ice dynamics along the Antarctic continent.

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Using under-ice hyperspectral transmittance to determine land-fast sea ice algal biomass in Saroma-ko Lagoon, Hokkaido, Japan

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Sea ice, which forms in polar and non-polar areas, transmits light to sea ice algal communities. To non-invasively study the distribution of sea-ice algae, algorithms to estimate its biomass using under-ice transmitted hyperspectra have been developed in the Arctic and Antarctica but are lacking for non-polar regions. This study, for the first time, examined the relationships between normalized difference indices (NDI) calculated from the hyperspectra, and sympagic algal biomass in the non-polar Saroma-ko Lagoon. We analyzed physico-biogeochemical properties of snow and ice supporting 27 paired bio-optical measurements along three transects covering over 250 m × 250 m in February 2019. Snow depth (0.084 ± 0.011m) and ice-bottom brine volume fraction (0.21± 0.02) have low (0.06) and high (0.58) correlations with chlorophyll a, respectively. Our NDI (636 nm,607 nm) explains 69% of algal biomass variability, similar predictability was achieved using ice-bottom salinity (68%) from literature. Our estimates overlap the observed range while others are over (561%) and underestimated (91%), suggesting the necessity of the bio-optical algorithm for non-polar areas. A hybrid estimation was introduced to increase the resolution of observations and unveil algal biomass structures. This algorithm can be applied to estimate sympagic algal biomass of Saroma-ko Lagoon using moorings and unmanned underwater vehicles.

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Sub-ice platelet layer in a one-dimensional thermodynamic sea ice model

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Land-fast sea ice grows due to conductive heat losses to the atmosphere. Near continental ice shelves, where Ice Shelf Water (ISW) exists at the ocean surface, fast ice also thickens because of interaction with the supercooled water column. This ISW creates specific sea ice forms: the porous, friable sub-ice platelet layer and incorporated platelet ice. However, their large-scale distribution and seasonality are not well documented, where model representations may help to progress the understanding of their role in the functioning of the Southern Ocean. This work introduces a representation of platelet ice processes in the one-dimensional Louvain-la-Neuve Sea Ice Model (LIM1D) based on mushy-layer physics. We evaluate the approach temporally by forcing LIM1D with meteorological observations and prescribed oceanic heat flux from an over-winter study in 2009 on the fast ice of McMurdo Sound, Antarctica. We evaluate simulation spatially along a ~20-km transect sampled in November 2009, applying reported oceanic heat fluxes and showing that measured and simulated sea ice and sub-ice platelet layer thicknesses agree within uncertainty range. Sub-ice platelet layers several meters thick are observed and simulated, and simulations highlight their low thermal conductivity and high heat capacity thermodynamically decouple the ocean from sea ice. Sensitivity experiments stress the roles of the oceanic heat flux, and insulating effect of deep snow that thickens the sub-ice platelet layer. Ultimately, the model not only help to understand the halo-thermodynamics within the layer and how this controls the sympagic biogeochemistry, but allows upscaling of these processes to the Southern Ocean scale.

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Low iron availability on ice algal photosynthesis: ex situ incubation of ice algae in artificial ice using a low-Fe ice tank

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Sea-ice algae are major contributors to the primary production of polar seas and also seed extensive ice-edge blooms. In the dynamic sea ice environment, they need to continuously acclimate their photosynthetic physiology to multiple co-stressors associated with ice formation and melt (i.e., freeze up: low temperatures and high brine salinity; ice melts: sudden high light exposure under chronic Fe starvation at the bottom of pack ice). The photophysiology of ice algae was investigated in a series of ice tank experiments with the sea ice diatom Fragilariopsis cylindrus under different Fe and light regimes. When algal cells were frozen into the ice, the maximum photochemical quantum yield (Fv/Fm) of photosystem II (PSII) sharply dropped, possibly because the high brine salinity suppressed the activity of downstream components of PSII. The algae within the ice showed almost identical levels of Fv/Fm regardless of iron and light availability, indicating that the diatom was capable of optimizing their photosynthesis during the frozen period. When the ice melted and the cells were exposed to high light, Fv/Fm sharply decreased, while non-photochemical quenching (NPQ) was less upregulated in low Fe treatments. Interestingly, the psbA gene encoding PSII reaction centres upregulated under high Fe conditions and vice versa. These results suggested that Fe availability significantly affected repair rates of the damaged PSII. Our results indicate that Fe-starved cells were not able to regulate their photosynthetic plasticity to the environmental changes. Ice algae would less contribute to ice-edge blooms if prolonged Fe deficiency occurs in their cells.

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The influence of snow on landfast sea ice in Prydz Bay, East Antarctica

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The observed snow depth and ice thickness on landfast sea ice in Prydz Bay, East Antarctica, were used to determine the role of snow in (a) the annual cycle of sea ice thickness at a fixed location (SIP) where snow usually blows away after snowfall and (b) early summer sea ice thickness within the transportation route surveys (TRS) domain farther from coast, where annual snow accumulation is substantial. The annual mean snow depth and maximum ice thickness had a negative relationship ($r = -0.58$, $p < 0.05$) at SIP, indicating a primary insulation effect of snow on ice thickness. However, in the TRS domain, this effect was negligible because snow contributes to ice thickness. A one-dimensional thermodynamic sea ice model, forced by local weather observations, reproduced the annual cycle of ice thickness at SIP well. During the freeze season, the modeled maximum difference of ice thickness using different snowfall scenarios ranged from 0.53–0.61 m. Snow cover delayed ice surface and ice bottom melting by 45 and 24 days, respectively. The modeled snow ice and superimposed ice accounted for 4–23% and 5–8% of the total maximum ice thickness on an annual basis in the case of initial ice thickness ranging from 0.05–2 m, respectively.

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SESSION 26

PREDICTING AND DETECTING TIPPING POINTS AND REGIME SHIFTS IN ANTARCTIC AND SOUTHERN OCEAN SYSTEMS

Delphi Ward, Nick Golledge

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Biotic and environmental responses to simulated permafrost degradation

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Permafrost degradation contributes to significant changes in soil hydrology, biogeochemical cycling, and soil communities by subsurface mobilization of water, biota and nutrients at the soil active layer. While climate warming can elicit such responses over years to decades, thawing events typically occur as discrete melt-water pulses. We simulated different frequencies of permafrost thawing events and characterized their associated impacts on soil communities and biogeochemical cycles in McMurdo Dry Valleys. We found that simulated permafrost thaw increases soil water content and heterogeneity in major ion content, as well as the structure of soil nematode communities. These effects are significant only at the patch scale, i.e., there are no significant plot level trends for either the pulse or press treatments, indicating that soil communities are resistant to massive water presses and pulses following permafrost thaw simulations over the time scale of five years. Treatments were statistically significant, but their ecological significance is subtle, perhaps only marginal compared with natural interannual variation. We discuss our findings in the context of ecological resistance and resilience, and the physical and biotic thresholds at which linear changes in structure and functioning emerge as non-linear, stabilized and reinforced regime shifts.

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Facing ecosystem collapse from Antarctica and the Subantarctic to the Tropics

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Ecosystem collapse, potentially irreversible change to ecosystem structure and function, imperils humans and global biodiversity. Systematic analyses of ecosystem collapse is urgently needed to successful risk mitigation strategies. Here, we examine the state and current trajectory of 19 collapsing ecosystems — spanning 58° of latitudinal range across 7.7 M km2, from terrestrial Antarctica, subantarctic islands to Australia's tropical coral reefs. We address the processes driving collapse and emerging patterns of change. Degradation is widespread, with all ecosystems showing evidence of local-scale collapse, but importantly none have collapsed across their full range. Climate change and regional human impacts have affected all ecosystems. We identified up to 17 pressures driving environmental deterioration, in response to increased temperatures and changes to precipitation combined with anthropogenic disturbances, occurring as chronic ('presses') and/or acute ('pulses') impacts. Pressures were often at unprecedented scale and severity. Habitat modification or destruction were the most common regional human impacts, but was least impactful in our Antarctica and subantarctic exemplars. We identified four collapse profiles (trajectories) — abrupt, smooth, stepped, and flickering. The breadth and range of collapsing ecosystems are a stark warning of the immediate need to address the ecosystem level challenge to conserve Nature upon which human wellbeing depends. Using insights gained from this analysis, we present a new three-step framework — awareness, anticipation and action —to mitigate against unprecedented and rapid environmental change and its accompanying risks to society and discuss the relevance of this framework to Antarctica, the Southern Ocean and associated ecosystems.

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Potential tipping points for life in the Southern Ocean: findings from an ACE-CRC report card

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There is now clear scientific evidence that climate change is causing rapid and unprecedented alteration of the Southern Ocean. These changes will have potentially serious impacts during the 21st century on the sustainability and management of many ecosystems. Anthropogenic alteration of pH, temperature, circulation and sea ice – along with potential for increased fishing pressure – are all likely to have far-reaching consequences for all species that currently inhabit the Southern Ocean. One of the fundamental questions is how climate change will alter the growth of key prey species including phytoplankton, zooplankton and krill. Phytoplankton are the base of the foodweb, and even small changes in sea-ice, ocean circulation, chemistry and temperature will affect which species live, thrive and die in the ocean. The biological outcomes from altered S. Ocean and Antarctic conditions will be determined by the environment, timing, rate and magnitude of change in each stressor, the order in which the changes occur, and the potential for consequences to be compounded when multi-stressors change concurrently. Hence, understanding climate change impacts on Southern Ocean biota requires us to consider which key species will be more sensitive to change, if change will have beneficial or detrimental effects, and how change will vary from regionally. These new insights will have important implications for management of fish stocks and high conservation-value species throughout the region. In this presentation we will provide an update on the latest developments in understanding the potential biological tipping points for the biota that comprise Southern Ocean ecosystems.

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Light driven tipping points in polar ecosystems

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Seasonal snow and ice-cover periodically block sunlight reaching polar ecosystems, but the effect of this on annual light depends critically on the timing of cover within the annual solar cycle. At high latitudes, sunlight is strongly seasonal, and ice-free days around the summer solstice receive orders of magnitude more light than those in winter. Early melt that brings the date of ice-loss closer to midsummer will cause an exponential increase in the amount of sunlight reaching some ecosystems per year. This is likely to drive ecological tipping points in which primary producers (plants and algae) flourish and out-compete dark-adapted communities. We demonstrate this principle on Antarctic shallow seabed ecosystems, which our data suggest are sensitive to small changes in the timing of sea-ice loss. Algae respond to light thresholds that are easily exceeded\ by a slight reduction in sea-ice duration. Earlier sea-ice loss is likely to cause extensive regime shifts in which endemic shallow-water invertebrate communities are replaced by algae, reducing coastal biodiversity and fundamentally changing ecosystem functioning. Modelling shows that recent changes in ice and snow cover have already transformed annual light budgets in large areas of the Arctic and Antarctic, and both aquatic and terrestrial ecosystems are likely to experience further significant change in light. The interaction between ice-loss and solar irradiance renders polar ecosystems acutely vulnerable to abrupt ecosystem change, as light- driven tipping points are readily breached by relatively slight shifts in the timing of snow and ice-loss.

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Investigating basal thaw as a mechanism of ice flow changes in Antarctica

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Glacial thermal processes exert a fundamental control on ice flow by governing, among other processes, the ability of ice to slide on its base. Frozen-bed regions are characterized by high basal traction and no basal sliding leading to reduced ice flow compared to regions with thawed beds. In Antarctica, some frozen-bed regions separate fast-flowing glaciers and ice streams. Others separate inland catchments with thawed beds from the grounding zone of marine ice-sheet sectors. If these frozen regions experienced thawing, this transition could lead to ice-sheet acceleration, reconfiguration, and retreat. We use the Ice Sheet System Model (ISSM) to identify regions of Antarctica that are likely to be just below the pressure melting point at the ice bed interface and assess the impact of thawing these vulnerable regions on the broader Antarctic evolution over century time scales. This is the first assessment of the large-scale impacts that thawing at the ice-bed interface could have across Antarctica, allowing us to evaluate its potential significance for the future evolution, stability, and sea level contribution of the ice sheet.

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Criticality of Plio-Pleistocene glacial cycles

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Ice-age cycles have been studied for nearly 200 years (Agassiz, 1841; Croll, 1864), with links between cycle frequency and periodic variations in Earth's rotation or celestial orbit now well-established (Milankovitch, 1930; Imbrie et al., 1984; Berger et al., 2005). Over the last five million years (the 'Plio-Pleistocene') the amplitude of glacial–interglacial temperature variability progressively increased and cycles became increasingly asymmetric (Lisiecki & Raymo, 2005), with most recent terminations taking place nine times faster than their preceding growth phases (Hays et al., 1976). To date, no single theory exists that explains this progressive, epoch-scale, evolution of the global climate system (Raymo & Huybers, 2008). Here we show that the Plio-Pleistocene climate system can be plausibly viewed as one that has incrementally evolved to one of increased efficiency, ultimately giving rise to glacial cycles characterised by a criticality that is expressed through abrupt terminations. In this framework, glacial maxima are the phase-space attractors to which the climate system gravitates, and terminations are triggered at the point when the system as a whole becomes critically unstable. Our results also suggest that future elevated atmospheric CO2 may prevent the climate system reaching the critical glacial state and instead faciliate a return to environmental conditions last seen more than 1–2 Ma ago.

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Ecosystem Thresholds and Tipping Points in the Soils, Streams, and Lakes of the McMurdo Dry Valleys, Antarctica

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The McMurdo Dry Valleys are the largest ice-free region of Antarctica. The soils, streams, and lakes of this landscape host communities of invertebrates, algae, and microbes. Whereas glacial meltwater streams dry up for most of the year and soils freeze, the lakes provide a stable liquid water column underneath their permanent ice covers (3-5 m thick). Through several short (1 season) and long term (30 years) experiments and observations in this landscape we have evaluated ecosystem responses to environmental changes (high/low melt seasons, warm/cold seasons, etc.). In the soils, changes to nutrient, salt, and moisture availability are the most likely to drive habitat changes. If warming increases meltwater production and movement across the landscape, the salts that move with that water in seeps and water tracks would likely cause a significant impact to these communities. To date, however, trampling is the most significant deleterious impact we have observed. In the streams, microbial and invertebrate communities are dependent upon both streamflow conditions and hyporheic processes (trapping organic matter, transforming nutrients). As such, a tipping point for streams would come with larger flows than we have observed mobilizing bed materials and biological communities to the closed-basin lakes. Having adapted to the light cycle of Antarctica under stable ice covers, lake communities would face a significant challenge if ice covers were to disappear, promoting greater transmission of summer light and substantial mixing. As the climate of the dry valleys changes in the coming decades, the ecosystem will respond, perhaps in ways heretofore unobserved.

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Implications of CO2-induced Antarctic marine microbial communities for the Antarctic coastal food web and biological pump: insights from network modelling

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Antarctic waters are among the most vulnerable to ocean acidification and in coastal areas elevated CO_2 has been shown to alter the composition of microbial communities. A six level, dose-response ocean acidification experiment was conducted on a natural marine microbial community in Prydz Bay, East Antarctica. This showed a strong tipping point in the structure and function of the microbial community between 634 – 953 µatm CO_2. CO_2 values above this tipping point, caused the microbial community to become dominated by smaller phytoplankton cells and bacteria. This data collected during the experiment was used to model the implications of these CO_2-induced changes in the microbial community on the Antarctic food web and biogeochemical cycles. Qualitative network modelling was conducted over a range of CO_2 scenarios suggests that these CO_2-induced changes would significantly alter trophodynamic pathways by changing the quality and quantity of energy available to higher trophic levels. Changes in nutrient uptake due to the shift observed in the phytoplankton community and an increased bacterial abundance would impact the availability and remineralisation of macronutrients through the microbial loop. ln addition, the shift to a community dominated by smaller cells could favour respiration of carbon in the microbial loop and reduce the rate of carbon sequestration in nearshore Antarctic waters. Thus, CO_2-induced changes in the microbial community composition in coastal Antarctic waters could reduce the energy available to higher trophic levels and the efficiency of the biological pump, resulting in a positive feedback to atmospheric CO_2 levels and global climate change.

1137

Present feedback between melting Antarctic Ice Sheet and warming Southern Ocean

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Strong heat loss and brine release during sea ice formation in coastal polynyas act to cool and salinify waters on the Antarctic continental shelf. Polynya activity thus both limits the ocean heat flux to the Antarctic Ice Sheet and promotes formation of Dense Shelf Water (DSW), the precursor to Antarctic Bottom Water. However, despite the presence of strong polynyas, DSW is not formed on the Sabrina Coast in East Antarctica and in the Amundsen Sea in West Antarctica. Here we show that freshwater input from basal melt of ice shelves partially offsets the salt flux by sea ice formation in polynyas found in both regions, preventing full-depth convection and formation of DSW. Here warm waters can flood the shelf and cause rapid melting. Our results suggest that a further increase in the supply of glacial meltwater to other shelf areas may trigger a transition from a cold regime (characterized by full-depth convection, low rates of ice-shelf basal melt, and active bottom water formation) to a warm regime (warm water at depth, high rates of ice shelf basal melt, and reduced bottom water formation). A slowdown of DSW formation in response to increased glacial meltwater input would have consequences for the deep overturning circulation and abyssal ventilation. At the same time, meltwater-induced changes in stratification would facilitate the spreading of warm waters across the continental shelf to ice shelf cavities, driving increased ice shelf basal melt, reduced buttressing of the Antarctic Ice Sheet, and additional rise in sea level.

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The Poles, Tipping Points and Earth System trajectories

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The polar regions play an exceptionally important role in the functioning of the Earth System. This talk will explore the role of the polar regions in this contemporary period of rapid change as the Earth System accelerates away from the relatively stable conditions of the Holocene and more deeply into the Anthropocene. The focus is on tipping elements in the Earth System and their role in potential tipping cascades that could strongly influence the trajectory of the Earth System as a whole. We will use control theory to assess the risk of initiating a tipping cascade over the next decade or two, where a global tipping point might lie, and what the outcome of a tipping cascade might be. Finally, we'll discuss the actions humanity needs to take - and their timing - the minimise the risk that we'll trigger a global tipping cascade and irreversibly put the Earth System on a trajectory to a fundamentally different state.

1192

Potential Tipping Points of Antarctic Ice Sheet Basins

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Antarctica is loosing mass in an accelerating way and these losses are considered as the major source of sea-level rise in the coming centuries. Ice-sheet mass loss is mainly triggered by the decreased buttressing from ice shelves mainly due to iceocean interaction. This loss could be self-sustained in potentially unstable regions where the grounded ice lies on a bedrock below sea level sloping down towards the interior of the ice sheet, leading to the so-called marine ice sheet instability (MISI). Recent observations on accelerated grounding-line retreat and insights in modelling the West Antarctica ice sheet give evidence that MISI is already on its way. Moreover, similar topographic configurations are also observed in East Antarctica, particularly in Wilkes Land. We present an ensemble of simulations of the Antarctic ice sheet using the f.ETISh ice-sheet model to evaluate tipping points that trigger MISI by forcing the model with sub-shelf melt pulses of varying amplitude and duration. As uncertainties
in ice-sheet models limit the ability to provide precise sea-level rise projections, we implement probabilistic methods to investigate the influence of several sources of uncertainty, such as basal conditions. From the uncertainty analysis, we identify confidence regions for grounded ice interpreted as regions of the Antarctic ice sheet that remain ice-covered for a given level of probability. Finally, we discuss for each Antarctic basin the total melt energy needed to reach tipping points leading to sustained MISI.

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Identifying Antarctic tipping points under past warming

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Ir-re-versible shifts of large-scale com-po-nents of the Earth sys-tem (so-called ‘tip-ping el-e-ments’) on pol-icy-rel-e-vant timescales are a ma-jor source of un-cer-tainty for pro-ject-ing the im-pacts of fu-ture cli-mate change. A wealth of geological, chemical, and biological records indicate large-scale and often irreversible shifts in the Antarctic took place in the past (centennial to millennial in duration). The forcing behind these changes appear to have been relatively small, implying specific thresholds, or tipping points were triggered (reached by self-reinforcing feedbacks), driving extreme, nonlinear changes across the Antarctic. Identifying past tipping points in ice-sheet stability is critical to projecting the response of Antarctica to future change and assessing potential for triggering tipping cascades across the Earth system. Generic rules can be used to identify early warning signals across the Antarctic and Southern Ocean that may be identified on the approach to a tipping point, generated from characteristic fluctuations in a time series as a system loses stability.

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Prediction, detection and characterisation of regime shifts in Southern Ocean ecosystems

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The potential for regime shifts - fundamental changes in ecosystem structure and function – is of great concern for Southern Ocean ecosystems. Growing awareness of the importance of regime shifts has triggered growth in research and development of analytical tools and approaches for predicting regime shifts (and to a lesser extent for detecting regime shifts once they have occurred). However, so far there is no unifying approach for ecologists and ecosystem managers wanting to evaluate an ecosystem for evidence of past regime shifts or the risk of future regime shifts.

We developed a framework for assessing the likelihood of regime shifts in ecological systems based on a review of theoretical and ecosystem case study literature. We identified a set of ecosystem qualities that increase risk of regime shifts, assessed existing capabilities for predicting and detecting regime shifts, and identified potential new approaches for doing so.

In this presentation, we present the application of this framework to Southern Ocean ecosystems. We highlight the data and methods currently available and suitable for assessing Southern Ocean ecosystems for regime shifts, and also gaps that could be targeted to maximise capability for predicting, detecting, characterising and managing such shifts in the future.

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SESSION 27

AEROMICROBIOLOGY, SNOW AND BIOGEOCHEMISTRY OVER ANTARCTICA

David Pearce
Stephen Archer, Tina Santl-Temkiv

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Survey of Viridiplantae present in Air and precipitated with Snow on Livingston island. (South Shetlands)

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We accessed Viridiplantae diversity present in freshly deposited snow and air samples at Livingston Island using DNA metabarcoding via high throughput sequencing (HTS). Two surface snow samples (>1500 mL each) were obtained shortly after precipitating, melted at room temperature and concentrated with Sterivex filters (0.22 µm pore size). Also, two air samples were collected with a High-Flow-Rate Impinger (340-400 m3 of air) into sterile MQ water and concentrated on Sterivex filters. Total DNA present was extracted and sequenced. In the snow, we detected 31 OTUs affiliating with Magnoliophyta (18), Bryophyta (1) and Chlorophyta (6). Trebouxia simplex was the most abundant Chlorophyta and Zea mays the most abundant Magnoliophyta. Microalgae affiliating with Trebouxia sp. have ice-nucleation activity and may have relevance for cloud and precipitation formation. In air, we found 12 OTUs affiliating with Chlorophyta (4), Bryophyta (1) and Magnoliophyta (7). Among Chlorophyta, the most abundant was Dictyosphaerium sp. and among Magnoliophyta, Monoon tirunelveliense. Only five OTUs were shared between air and snow, which likely reflects the different air masses that were collected. Also snow forms at higher altitude and is likely dominated by taxa arriving though long-range dispersal. Air sampled at ground level is likely dominated by taxa from local sources. The presence of maize, a tropical crop, was unusual, but as one of the most abundant crops in the world is not unlike it may spread via atmosphere. It is important to stress that detecting the DNA of a species does not mean that the species is present.

1325

Excess carbon induces carbon storage as polyhydroxyalkaonate (PHA) production in Antarctic sea-ice bacteria

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Sea-ice organisms experience fluctuating and harsh environmental conditions such as low temperature, high salinity and intermittent substrate supply. Bacteria in sea ice have various strategies to survive in the ice (e.g. compatible solutes and EPS-production), however, these mechanisms are not thoroughly understood. Polyhydroxyalkaonates (PHAs) are polyesters that serve as a pool for carbon storage and are readily available for different cellular processes. Interestingly, PHA is also used in bioplastic production, for which sea-ice bacteria may serve as potential production organisms i.e. due to their low temperature optima. PHA granules and phaC synthase genes have been detected in sea-ice bacteria, however, their production mechanism and ecological significance is not known. Our aim was to investigate whether or not sea-ice bacteria are capable of PHA production and to elucidate the cellular mechanism behind it.
PHA production was tested with two bacterial isolates, Paracoccus (Alphaproteobacteria) and Halomonas (Gammaproteobacteria), isolated from Antarctic sea ice. PHA production was verified with transcriptomic, microscopic and GC-MS methods. Also, the occurrence of phaABC genes were also detected from several Antarctic, Arctic and Baltic Sea ice metagenomes.
These results demonstrate that Antarctic sea-ice bacteria are capable of producing PHA. We hypothesize that PHA production in ice is related to the ephemeral feature of labile dissolved organic carbon availability (i.e from the initial freezing). Thereafter carbon PHA granules are stored to enhance survival within ice.

1444

Bacteria living on air: Atmospheric chemosynthesis supports primary production in cold desert soils

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Antarctica is the coldest, driest and windiest continent on the planet. Yet the desert soils of Antarctica host a great diversity of microbial communities that have evolved unique strategies to survive under the extremely harsh conditions. Microbes dominant terrestrial Antarctica and in doing so must endure frequent freeze-thaw cycles, complete winter darkness, limited nutrient and water availability and intense UV radiation. We have discovered that in the dry desert surface soils of the Windmill Islands and Vestfold Hills regions, Eastern Antarctica very few phototrophs such as cyanobacteria or algae exist. Instead, novel bacterial phyla with new functional capacities are thriving under these stressful conditions. By combining metagenomics with differential coverage binning and functional assays we proposed that atmospheric chemosynthesis, a new form of primary production was supporting microbial communities living in these cold, nutrient poor environments. This aerobic energy-capture process relies on the oxidation of atmospheric levels of hydrogen and carbon monoxide gas to provide the fuel required to fix CO2 via the Calvin-Benson-Bassham cycle and provides new understanding of the nutritional limits required for life. Today I will focus on the significance of this alternative form of primary production, by providing new evidence that soil microbiomes across the three poles also perform atmospheric chemosynthesis. At the same time, I will provide new information on the physiology and environmental drivers of bacteria with the genetic capacity to live on air, particularly focusing on Candidatus Eremiobacteraeota (WPS-2), a yet-to-be cultured bacterial phyla.

1300

Airborne microbial communities along a zero-emission traverse on the Antarctic Plateau

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Despite the harsh environmental conditions of the Antarctic plateau, microorganisms can be found in the air. In this communication we present the Windsled expedition, conceived as an ultra-clean scientific campaign, perfectly adapted to our purposes of investigating the microbial community in the plateau's atmosphere. Extreme cold conditions, absence of a non-renewable energy source and constant shocks caused by the movement of the WindSled when passing over the sastrugi, were a technological challenge that required development of new methods and instruments. The expedition covered a transect of 2,538 km in 52 days, in which 62 air samples were collected with three specially designed zero-emission collectors that operated with different configurations to maximize the capture of airborne microorganisms. Environmental data was also recorded using the adapted automatic weather station M-AWS. Position, temperature and relative humidity were recorded every 30 minutes, providing a dataset of 1,732 measurements for each variable at 522 different locations. Overall in this expedition we captured an average of 8.31×10^2 cells per m^3, with a standard deviation of 1.06×10^3 cells per m^3, indicating extremely high variability in the airborne bacterial concentrations. The relationship of this variability with the environmental conditions is analyzed. Our results indicate that the Windsled is an excellent vehicle for these remote and extreme locations, allowing scientific projects to be developed under the principle of inexpensive transits, zero emissions and ultra-clean technologies.

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Active and Dormant Antarctic Snow Algae Reduce Coastal Snow Albedo

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Snow algae bloom is a common occurrence in coastal snowpacks of the northern Antarctic Peninsula and adjacent islands during austral summer. We collected surface spectral albedo and total chlorophyll concentrations from three algae bloom sites in the Antarctic Peninsula region. Here snow algae is comprised of green algae (chlorophyta) that appear green during reproduction and red during dormancy. Spectral albedo in areas of intense algae bloom was reduced in the visible wavelengths to 0.49 (red communities), 0.49 (mixed) and 0.31 (green). Relative to clean snow, the reproductive green-phase snow algae reduced snow albedo in the visible wavelengths by up to 61%, almost three times more than the dormant red-phase, 24%. Also, algal biomass in the snow was well-correlated with albedo reduction, (r2 = 0.68). Given the intense warming in the region over the past 6 decades, it is likely that the snow algae bloom season has been extended, exacerbating melting and snow retreat in coastal snow areas. These data may eventually be used in algorithms aimed at mapping the spatial and temporal variability of snow algae across their reproductive phases and tracking algal bloom expansion using multi-spectral satellite remote sensing.

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Mat-building ability of Antarctic cyanobacteria strains

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On the Antarctic continent, where the extreme climate places severe limitations on terrestrial life, cyanobacteria form a range of complex mats, across a variety of aquatic and semi-aquatic habitats. Mat formation is often thought to benefit survival under adverse conditions. It is a challenge to understand the interactions among mat-forming microorganisms and which organisms benefit most from, or are most active in the production of, the mat morphology. Here we examined the production of microbial mats role by individual strains and mixed cultures of five cyanobacteria belonging to the Nostocales, Oscilatoriales and Chroococcales orders, isolated from Antarctic mats. The results were focusing on the chlorophyll-a, exopolysaccharide and organic matter production. Despite, some morphotypes performing better than others, we did not find strong evidence that mixed cultures performed better than the best single isolates. To a large extent different strains were able to “substitute” for each other in forming a mat, indicating the potential for a resilient response to changing stress profiles. The morphotype Phormidium cf. autumnale showed the best performance displaying greater production of EPS, organic matter and Chl-a contents.

1328

Living on Air- Antarctic bacteria that use atmospheric trace gasses to survive and thrive.

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Antarctic soil is known to contain unique microbial communities as a result of the isolation and extreme environmental conditions experienced in Antarctica. This study has focused on an enigmatic bacterial phylum found in high proportions within Antarctic soils. Formerly known as Candidate Division AD3, Ca. Dormibacteraeota are found in soils across the globe, usually representing less than 1% of the microbial community. In arid desert soils from Robinson Ridge and Mitchell Peninsula in Eastern Antarctica, Ca. Dormibacteraeota represented up to 15% of the microbial community, suggesting that they thrive under these harsh conditions. We used shotgun sequencing and differential binning of soils from these two sites to obtain six metagenome assembled genomes (MAGs) belonging to this phylum. The MAGs provided insight into the lifestyle and survival strategies of these bacteria. Of primary interest was the ability of the microbes to assimilate carbon dioxide and carbon monoxide as a carbon source while using atmospheric hydrogen gas as an energy source. Further experimentation using stable isotope probing confirmed the ability of the microbes to assimilate carbon dioxide from the atmosphere using 13CO2. Finally, we aimed to visualise the cells using a range of fluorescent in-situ hybridisation (FISH) techniques which revealed the cells to be small cocci approximately 250-300 nm in length. We conclude that the unique ability of Ca. Dormibacteraeota to assimilate trace gasses from the atmosphere and their small size and shape make them uniquely adapted to the Antarctic environment, allowing them to thrive.

1693

Microbial diversity and prediction of ecological processes beneath the West Antarctic ice sheet

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Non-aquatic subglacial ecosystems in Antarctica may be spatially more extensive and variable in physical-chemical characteristics when compared to the subglacial aquatic habitats, however their microbial diversity is still poorly explored. In this study, we aimed to understand the microbial community structure deposited on the West Antarctic ice sheet through 16S rRNA gene sequencing, followed by a prediction of the metabolic and ecological processes. We aseptically excavated a pit structure near Criosfera1 remote Brazilian laboratory/CrioLab1 (670km from south pole), in which we collected snow/firn samples among six different depths between the surface and 200cm. The abundant phyla were classified as Proteobacteria, Firmicutes, Parcubacteria, Cyanobacteria, Bacteroides, Actinobacteria, Thaumarchaeota, Marinimicrobia, Woesearchaeota, Euryarchaeota and Chloroflexi. We found a higher proportion of marine members within Thaumarchaeota and Thermoplasmatales at the superficial strata, whereas Cyanobacteria was detected mainly at the deeper layers. Atmospheric modeling of air incursions at the study site suggest a high marine influence from the Weddell and Indian sea, as well as from the sub-antarctic environment. We also detected sequences classified as hyperthermophiles within Aquificae and Euryarchaeota. Microorganisms associated with nitrogen metabolism were more abundant among deep layers (110-180 cm), while those in superficial layers were related to functions as chemoheterotrophy, degradation of aromatic compounds and animal parasites and symbionts. The prevalence of members that occupied such distant ecosystems as marine, hydrothermal and animal bodies suggests a heterogeneity of the ice-sheet microbiome probably due to the largely aeolian dispersion over the Antarctic continent and their long-time persistence in this extreme and isolated environment.

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Geomicrobiology studies in the Ellsworth Mountains, Antarctica; interaction of microorganism with rocks as a strategy to survive in this hyper-extreme environment.

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Close to the Chilean Union Glacier scientific camp, located in the Ellsworth Mountains about 1000 km from the South Pole, is the mountain called Elephant Head. This zone presents temperatures below freezing throughout the year and high UV radiation during the summer. Mineralogical and elemental composition of Elephant Head soil samples were determined through XRD and SEM-EDS, respectively. XRD analysis revealed the presence of calcite, dolomite, and quartz, and the elemental analysis revealed the presence of O, Si, Ca, Al, K, Mg, and Fe. Also, using X-ray microtomography (Micro-CT) we determined that the rocks of this site have greater porosity than those found in other areas of the Ellsworth Mountains (Mount Rossman or Charles Peak).
Through 16s rRNA gene sequencing we identified the microorganisms present in soil samples obtained during two campaigns (2017 and 2018) at different depths and altitudes on Elephant Head. Obtained results revealed the presence of cyanobacteria (particularly in surface samples), a result that allowed us to establish possible associations between the type of rock present in Elephant Head and the microbial communities. In this sense, quartz is a translucent mineral that permits the passage of light inside the rock and considering their porosity could act as a shelter protecting the microorganisms from hyper-extreme environmental conditions allowing a light-driven metabolism mediated by cyanobacteria.
Finally, we isolated endolithic bacteria and we are studying their potential in biomineralization processes to understand mineral-bacteria interaction. In particular we studied calcite bioprecipitation and the generation of metal nanocrystals.

1290

New zero emissions collector for the capture of airborne microbes in the Antarctic Plateau.

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Air Sampling has been demonstrated a complex task with some crucial aspects that may create difficulties in the interpretation of results. When airborne microorganisms are to be collected from extreme remote locations with extremely low cell concentration, as the Antarctic Plateau, adapted capturing methodologies should be developed. We present the methodological development of an airborne bacterial capturing technology created specifically for an Antarctic Plateau transect (2540 km) , the Antarctica Unexplored Expedition 2019, with very limited energy availability. We present the capturing technology and methodology for the analysis of bacterial community collected from the Antarctic Plateau's atmosphere. We measured airborne cellular concentration, assessed its potential viability by flow cytometry and extracted DNA for sequencing. The collector consisted of a forced air system with a precise air flow and a turbine that converted the flow in turbulent before the retaining device based on a solid petroleum jelly, which remained viscous at extremely low temperature. The energy demand of the system was very low and handy solar panels provided the requirements. Cell extraction from the viscous matrix was optimized in the lab, and allowed high recovery rates, antibody identification, staining and flow cytometry analyses and DNA sequencing of the airborne community. We collected 62 samples from which we have obtained microbial airborne concentration, its viability through membrane integrity and the molecular identification of those microbes.

1289

Bacterial diversity in the Antarctic plateau atmosphere and accumulated snow

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The extreme environmental conditions dominating the Antarctic Plateau constrain the biological activity in this extensive continent. The WindSled expedition navigated the Antarctic Plateau in a special wind-powered vehicle for 52 days and 2538 km. Air samples were collected using a collecting device designed ad-hoc for the expedition along this transect. The airborne cells collected were enumerated by flow cytometry and identified by fluorescence microarray immunoassay with a life detector chip (LDChip) and massive 16S rRNA gene sequencing. Simultaneously, samples from snow profiles (down to 4 m depth) at three sites were obtained and analysed in situ with LDChip and DNA sequencing in the laboratory. In this communication we discuss the differences in the bacterial communities found in both matrixes (air and snow) considering that biological activity at the plateau should be extremely low (given summer mean temperature was -30 ˚C during the expedition) and thus the bacterial composition of the air community should be a combination between the advent of cells from snow fields in Antarctica and those coming from long range wind trajectories. In this study, we also investigate the long-range trajectories of the air masses that transport cells during the capturing period. We discuss our hypothesis about the Antarctic Plateau as an immense airborne bacterial trap that accumulates cells (i.e. DNA) from different regions on Earth.

1212

Uncultured fungal diversity in recent superficial snow on Livingston Island, Antarctica

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We assessed uncultured fungal diversity present in freshly deposited snow and in air samples obtained from Livingston Island, Antarctica, using the DNA metabarcoding through high throughput sequencing (HTS). Superficial snow obtained shortly after deposition was kept at room temperature and yielded 3.760 L of water, which was filtered using sterivex membranes (0.22 µm). Also, 740 m3 of air at the same region were pumped through an 0.22 µm membrane. The total DNA present in the membranes was extracted and sequenced. In the snow sample, we detected 97 fungal operational taxonomic units (OTUs) dominated by the phyla Ascomycota, Basidiomycota, and Mortierellomycota. The fungal assemblages present in the air and recent snow displayed high diversity and richness, but low dominance indices. Twenty-seven OTUs occurred only in the air, 30 in snow, and 36 in both samples. Within both the air and recent snow communities, the Ascomycota taxa Cladosporium sp. and Pseudogymnoascus roseus were dominant (>20,000 reads). Use of an HTS approach revealed the presence of more diverse fungal communities than have been detected using traditional isolation methods. The communities included cold-adapted and cosmopolitan taxa. Evidence of their presence in the airspora supports the possibility of dispersal around Antarctica in the air column. Further aeromicrobiology studies are required to understand the dynamics of fungal dispersal within and beyond Antarctica.

1532

Potential export of organic carbon and nutrients from the coastal Antarctic ice sheet

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Physico-chemical and biological processes could influence the concentration of crucial biogeochemical components on glacier surface and those discharged to aquatic environments through melt water runoff. Here, we present data on the spatial and temporal variation of the chemistry of surface glacier samples collected along a 1.2 km transect (45 day period, 11 day interval) during summer. Samples were collected beginning at the ice cap in Grovnes peninsula, Larsemann Hills (East Antarctica), where meltwater from snow slush feeds a glacial stream before traversing through a cryoconite hole zone and eventually discharging into the Thala fjord. High debris loading on snow surface resulted in reduced albedo compared to clean snow, contributing to increased melting in this region. Concentration of major inorganic ions (Na^+, Ca^{2+}, K^+, Mg^{2+}, Cl^-, SO_4^{2-}, NO_3^-) did not change substantially along the transect, but increased towards the end of melt season. Dissolved organic carbon concentrations in snow were below detection limit at the beginning, but increased considerably towards the end (up to 839.0 μgL^{-1}) of the season, indicating high biological activity on the glacier surface during summer. Trace element (Al, Mn, Ni, Cu, Se, Sr, Ba, Fe and Si) concentration increased in the order clean snow < dirty snow < meltwater < cryoconite holes, and was higher at the end, compared to the beginning of melt season. The high concentration of chemical constituents in the melt water suggests that during summer, the coastal Antarctic sheet could be an important contributor to DOC and nutrients to the surrounding coastal waters.

1025

Reconstruction of the Functional Ecosystem in the High Light, Low Temperature Union Glacier Region, Antarctica

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The identity and functionality of microorganisms from polar glaciers are defined. However, little is known about microbial communities from the high elevation glaciers. The Union Glacier, located in the inland of West Antarctica at 79°S, is a challenging environment for life to survive due to the high irradiance and low temperatures. Here, soil and rock samples were obtained from three high mountains (Rossman Cove, Charles Peak, and Elephant Head) adjacent to the Union Glacier. Using metagenomic analyses, the functional microbial ecosystem was analyzed through reconstruction of carbon, nitrogen and sulfur metabolic pathways. A low biomass but diverse microbial community was found. Although archaea were detected, bacteria were dominant. Taxa responsible for carbon fixation were comprised of photoautotrophs (Cyanobacteria) and chemoautotrophs (mainly Alphaproteobacterial clades: Bradyrhizobium, Sphingopyxis, and Nitrobacter). The main nitrogen fixation taxa were Halothece (Cyanobacteria), Methyloversatilis, and Leptothrix (Betaproteobacteria). Diverse sulfide-oxidizing and sulfate-reducing bacteria, fermenters, denitrifying microbes, methanogens, and methane oxidizers were also found. Putative producers provide organic carbon and nitrogen for the growth of other heterotrophic microbes. In the biogeochemical pathways, assimilation and mineralization of organic compounds were the dominant processes. Besides, a range of metabolic pathways and genes related to high irradiance, low temperature and other stress adaptations were detected, which indicate that the microbial communities had adapted to and could survive in this harsh environment. These results provide a detailed perspective of the microbial functional ecology of the Union Glacier area and improve our understanding of linkages between microbial communities and biogeochemical cycling in high Antarctic ecosystems.

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SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 28

HUMAN IMPACTS IN ANTARCTICA IN A CHANGING CLIMATE

Susan Bengston-Nash
Catherine King, Andreas Zimbelli

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

1259

Polycyclic aromatic hydrocarbons and heavy metals content in soils of vicinities of Russian Antarctic stations

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Antarctica is considered as one of the most pristine areas on Earth. However, increasing rates of human presence on the sixth continent makes it crucial to investigate the level of environmental pollution within the vulnerable ecosystem of Antarctica. Soils have a significant role in processes of accumulation, mobilization, redistribution of chemical, and especially, trace elements in landscapes and ecosystems. The aim of this work was to analyze the levels of 17 polycyclic aromatic hydrocarbons (PAHs) and 8 heavy metals (HMs) in the vicinities of Russian Antarctic stations both in Eastern and Western Antarctica. Moreover, our work is aimed to determine the trends and reasons of anthropogenic pollution of Antarctic soils and characterization of accumulation levels of HMs and PAHs. Results show the predominance of light PAHs in all studied sites with prevalence of low-molecular polyarenes. The content of benzo(a)pyrene does not exceed the maximum permissible concentrations (adopted in Russia). At the same time the content of benzo(a)pyrene, which is a marker of anthropogenic contamination, is relatively low or equal to 0 in soils of reference-landscapes. Generally, geoaccumulation index values for heavy metals were under or slightly above the 0 level, indicating low to moderate pollution of the studied soils. However, considerable Igeo values of Zn, Pb and Cu were revealed in several samples. Results obtained in our study are especially relevant in sense of climate change effects as a long-term and gradual warming in Maritime Antarctica.

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Microplastics in the Antarctic coastal environment of Potter Cove

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Marine plastic pollution has become a global issue affecting even the most remote regions of the ocean. Microplastics pollution (plastic particles <5 mm size) in Antarctica has recently started to be studied and consequently, there are still many knowledge gaps regarding its concentrations, characteristics and potential impacts on the ecosystem. We performed the first detailed analysis of microplastic debris concentration, distribution and composition in Potter Cove (King George Island/25 de Mayo, South Shetlands, Antarctica). Four transects were sampled following the water circulation within the cove, including one in front of the Scientific Station Carlini, to characterize the plastics and infer their origin. An intensive surface sediments sampling by means of SCUBA diving was accompanied with water column (5 and 20 m depth) sampling using three complementary methods: plankton net (263 µm), 5 L Niskin bottles, and an in situ filtering device named Microfilter that allowed filtering relatively larger volumes of water (average 115 L per sample) through a 47 µm stainless steel mesh. Recovered microplastics were photographed, and measured using image analysis software (Image J) and analyzed by Raman spectroscopy to reveal their polymeric composition. Preliminary results showed fragments, spheres of different sizes and colors, being the majority smaller than 100 µm. As the primary risk of microplastics is their bioavailability to marine organisms, further studies are needed to investigate the trophic transfer, bioaccumulation and their ultimate fate in Antarctic ecosystems. Such studies are planned for next Antarctic campaigns.

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Microplastics at the intertidal of the South Shetland Islands (Antarctica)

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During several decades we have been studying marine benthic invertebrates in Antarctica. We observed plastic debris in some benthic invertebrates collected recently and thus decided to investigate how much plastic is in the sediments and water surrounding these benthic organisms. Our research group has been evaluating the presence of microplastics in the intertidal areas of several islands in the South Shetland Archipelago, where samples were collected at Livingston and Deception Islands. These samples have been studied by separating and identifying the material, characterizing and analyzing the debris obtained, and these have been also photographed and measured. A protocol was adopted to separate the plastic debris from the samples, according to the literature and our own inputs. Five samples were taken from the upper part of the intertidal zone and another five from the lower part and were stored in glass jars with alcohol. We present here the analyses of some of these samples and their plastic content.

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Brominated Flame Retardants in Antarctic Air in the Vicinity of Two All-Year Research Stations

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Polybrominated diphenylethers (PBDEs) are a group of organohalogen compounds used extensively in consumer products over the past 50 years. Their environmental behaviour of persistence and long range dispersal, combined with their biological impacts of accumulation within organisms with potential toxicological effects, has led to the banning of the majority of PBDE formulations under the Stockholm Convention. PBDEs have been reported in Antarctic biota since 2004, and in the Antarctic atmosphere since 2012. Unlike organochlorine pesticides, the Antarctic occurrence of which can be attributed solely to Long Range Environmental Transport, current and recently-used chemicals, such as PBDEs, are also finding their way to the remote Antarctic region via in-situ usage. Recent studies focusing on Antarctic research stations as emitters of PBDEs to the local environment, have evidenced local pollution and consequently implicated all Polar research stations as local sources of these compounds. In this study we conducted year-long atmospheric sampling for PBDEs in the vicinity of Troll and Casey, two all-year research stations. Significant differences in atmospheric levels of PBDEs were observed between the two stations, with elevated levels observed at Troll. Particularly levels of BDE-47 detected in Troll air were higher than those previously detected in Antarctica and similar to those found in densely populated regions such as Southern Taiwan. Whilst on-station PBDE sources at both Casey and Troll stations remain unidentified, the atmospheric PBDE levels observed in the vicinity of these active research stations emphasise the growing importance of local sources of chemical pollution for the Antarctica region.

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Microplastic in the Antarctic marine food web: a first assessment

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Microplastic pollution is known to have reached even the most remote and pristine regions of our planet including Antarctic waters. Studies show that plastic particles can be ingested by marine biota with potential adverse implications on individuals and the food chain.
Antarctica is of particular importance as many species are highly adapted to the extreme Antarctic climate and an additional stressor could raise their vulnerability. Furthermore, plankton and benthic communities from the Southern Ocean play a key role in the global marine food web.
This study focuses on the environmental consequences of microplastic ingestion for Antarctic marine invertebrates and the possible effects in higher trophic levels. Sampling took place in the Antarctic summer 2020 from three representative fjords with documented glacier retreat along the Antarctic Peninsula and on Burdwood bank in the South Atlantic.
The vulnerability towards microplastic will be assessed using traits such as feeding type, habitat, functional group and trophic level. We aim to investigate what factors influence the rate of microplastic ingestion and to determine whether it bioaccumulates through the food web. First analysis of water samples shows microplastic presence in all sampled fjords along the Antarctic Peninsula. The chemical identity of these plastics will be confirmed using Fourier-Transformed Infra-Red spectroscopy (FTIR).

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Assessing impacts of contaminated sites in Antarctica: application of toxicity tests with native soil micro-invertebrates

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Toxicity tests are used routinely worldwide to assess impacts of contaminated sites, and are fundamental to the derivation of Environmental Quality Guidelines and Remediation Targets. However, to date, few protocols have been developed using native Antarctic species, especially for terrestrial systems, and sensitivity data is limited. Plectus murrayi is a common and ecologically important nematode worm inhabiting soils Antarctic wide. Optimal culturing techniques have been developed with this species, and robust toxicity test procedures using the most sensitive juvenile stage are now standardised for site-specific Environmental Risk Assessments. Here we present results of toxicity testing for common pollutants including metals and fuels. For copper, the response of nematodes was dependent on the life history stage tested and on the duration of exposure, with sensitivity of juveniles increasing through time, and 50% lethal concentrations (LC50) of 478 and 117 µg/L at 21 and 28 d, respectively. For fuels, the toxicity of fresh and aged diesel contaminated soil (up to one year of weathering) was assessed in elutriates prepared using soil from Casey station spiked with Antarctic diesel. Exposure concentrations for hydrocarbons were quantified through a suite of chemical analyses on soils and elutriates. Toxicity was influenced by the presence of hydrophillic polar and non-polar compounds, with aged fuel generally less toxic than fresh fuel. Critical effect concentrations generated for P. murrayi, along with other terrestrial biota, contribute valuable data towards the development of Soil Quality Guideline Values and Remediation Targets for site restoration and soil reuse at contaminated sites in Antarctica.

1050

Microplastic in South Georgia Plankton: A study of the level of microplastic ingestion seen in planktonic organisms which form the base of the regional foodweb.

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Microplastics are ubiquitous in the global ocean and have even been found in remote polar environments. The ingestion of microplastic by zooplankton and krill has been well documented; this study will assess the microplastic loads of the ecologically significant keystone species, Euphasia superba, and other planktonic organisms in the nearshore waters of South Georgia. It is hypothesised that A) microplastic will be present inside the plankton, having been accidentally ingested; and B) that contamination loads will be of a level which will explain the presence of microplastic recently documented in planktivorous seabird species from the same area (Bessa et al, 2019; Le Guen et al, 2020).
Samples from the long-term plankton monitoring sites Rosita Harbour and Cumberland East Bay (CEB), dating back to 2008, will be analysed in order to estimate the change in microplastic exposure over time, which planktonic organisms in the region have been subject to.
This study will present the optimal methodology for extracting microplastics from chitinous organisms through organic digestion. Suspected anthropogenic particles, extracted from the plankton samples, will undergo polymer analysis via Fournier-Transmission Infrared (FT-IR) Spectroscopy. We predict that microplastic loads will be higher across all various taxa in plankton from CEB, as it is subject to more frequent and intense anthropogenic activity than in Rosita Harbour.
Future work will constitute examining the microplastic loads in planktivorous predators in the same region i.e. demersal and pelagic fish and their predators to assess the potential for microplastic trophic transfer.

1347

Anthropogenic activities are associated with shorter telomeres in chicks of Adélie penguin

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Defining the impact of anthropogenic stressors on Antarctic wildlife is an active aim for investigators. Telomeres represent a promising molecular tool to investigate the fitness of wild populations, as their length may reliably predicts longevity and survival. We examined the relationship between telomere length and human exposure in Adélie penguin chicks (Pygoscelis adeliae) from East Antarctica. Telomere length was compared between chicks from areas with sustained human activity (Petrels Island) and on neighboring islands with little or no human presence (Lamarck and Bernard Islands). Adélie penguin chicks from disturbed sites had significantly shorter telomeres than chicks from undisturbed sites in nearby protected areas. While more data is needed on the ultimate impact of human disturbance on penguin colonies, our analysis nonetheless provides important insights into colony vulnerability. We suggest to further test the use of telomere length analysis as an eco-indicator of stress in chicks of Adélie penguins, and other penguin species, among anthropized sites throughout Antarctica. Telomeres could indeed be a relatively easy to use marker to inform the Committee for the Polar Environment at the Antarctic Treaty System on the impact that Antarctic stations or recurrently visited landing sites by tourists have on bird colonies.

824

Relationship between antibiotic resistance patterns found in bacteria isolated from seawater and bacteria isolated from sewage from Antarctic Stations

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In this work, wastewater and seawater samples collected from different points in Antarctica were examined for the presence of bacteria with antimicrobial resistance
The samples of sea water were collected from sites distributed around the sewage outfalls of six Antarctic stations. Wastewater samples were taken from three Antarctic wastewater treatment plants (WWTP). Additionally, control samples were collected from pristine sites.
Escherichia coli strains were isolated from wastewater and seawater and antibiotic susceptibility patterns were determined with the disk diffusion method using different groups of antibiotics: penicillins, cephalosporins, carbapenems, aminoglycosides, quinolones, tetracycline, phenicols, sulphonamides, and trimethoprim. Escherichia coli ATCC 25922 was used as the control for the susceptibility tests.
A total of 227 E. coli isolated strains were studied to determine antibiotic susceptibility (191 strains from seawater and 36 strains from wastewater). 59% strains from seawater were resistant to at least one antibiotic and 33% were multidrug-resistant. Additionally, 36% of the strains from wastewater were resistant to at least one antibiotic and 22% were multidrug-resistant. E. coli were not detected in the control samples.
E. coli strains isolated from wastewater showed patterns of antimicrobial resistance similar to those found in isolated strains from seawater near sewage outfalls. These results suggest that the presence of bacterial with antimicrobial resistance in Antarctic seawater could be the result of wastewater discharge from WWTPs from Antarctic stations.

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Amplification of Persistent Organic Pollutants at Coastal Antarctica

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Many legacy and emerging persistent organic pollutants (POPs) have been reported in polar regions, and act as sentinels of global pollution. Maritime Antarctica is recipient of abundant snow precipitation. Snow scavenges air pollutants, and after snow melting, it can induce an unquantified and poorly understood amplification of concentrations of POPs. Amplification of concentrations of surface-active and hydrophobic POPs can also occur in the marine surface microlayer (SML). Air, snow, the fugacity in soils and snow, seawater, the SML and plankton were sampled in three sampling campaigns at Livingston and Deception Islands (South Shetland, Antarctica), and analyzed for polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs), perfluoroalkyl substances (PFASs), polycyclic aromatic hydrocarbons (PAHs) and organophosphate esters (OPEs). Coastal seawater mirrored the pollutant profile in snow, consistent with the amplification of concentrations in snow and the snowpack releasing POPs to seawater during the austral summer. The influence of snowpack and glacier inputs was further evidenced by the correlation between net volatilization fluxes of semi-volatile POPs and seawater salinity. In addition, there was an amplification of PFAS in the SML and aerosols, supporting the role of sea-spray aerosol as a vector for long-range atmospheric transport of PFAS. These results further indicate that amplification of concentrations in snow and the SML contribute to the generalized occurrence in Antarctica of legacy and emerging organic pollutants with a wide range of physical chemical properties and confirms the role of polar regions as a sentinels of global pollution.

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Overwintering strategy and susceptibility of an Antarctic freshwater zooplankton to anthropogenic chemicals.

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Zooplankton in freshwater lakes on all continents store dormant embryos in sediments for years to centuries, but this survival strategy may make zooplankton more susceptible to anthropogenic chemicals. Published data demonstrate that persistent organic pollutants (POPs) are accumulating in Antarctica, and exposures of Antarctic species to POPs now cooccur with a rapidly changing climate. Unfortunately, few studies provide data to help predict the impact of anthropogenic chemicals and climate change on freshwater zooplankton in Antarctica. To determine if zooplankton are exposed to common lipophilic pollutants in Antarctic freshwater lakes, we tested bottom sediments of lakes on King George Island for polychlorinated biphenyls (PCBs). The data presented here demonstrate that PCBs found in lake catchments are also found in lake sediments where dormant zooplankton are located. Permeability tests with rotenone show that moderately lipophilic chemicals penetrate embryos of the freshwater copepod, Boeckella poppei. Frozen sediments may provide a safe-zone for dormant embryos by partially immobilizing chemicals, but field data indicate that B. poppei on King George Island overwinter in both frozen and unfrozen sediments. Embryo densities are highest in sediments that do not freeze, in part because freeze tolerance is dependent on the rate of temperature change and minimum temperature. Together, these findings suggest that moderate warming in Antarctica will not present a problem for overwintering embryos of B. poppei. However, the impacts of lipophilic pollutants on zooplankton will increase if lake sediments do not freeze. An assessment of dormant freshwater zooplankton and anthropogenic pollutants along the Antarctic peninsula is needed.

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Impact of human activities on the arrival of non-native species to the Antarctic ecosystems.

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Current effects of climate change and the exponential increase of human activities make the Antarctic ecosystem have a high invasiveness. In this context of global change, quantify the biological particles (pollen and seeds) in the soil of the Antarctic Peninsula can be helpful from a conservative management. In this study, we identify and quantify seeds and the current pollen rain deposited in the topsoil in the Antarctic Peninsula region. First, we sampled topsoil in Fildes Peninsula, King George Island, an area of high human impact due to the scientific and logistical activities, we select three sectors: a strongly affected, a less visited and a with low human activity. Second, we sampled topsoil in Deception Island, Hannah Point and Hurd Peninsula in Livingstone Island and close to Arctowski Station, Admiralty Bay, King George Island with the aim of expanding the coverage area. The results indicate a direct correlation between the sites of greatest anthropization and the presence of seeds and pollen taxa of non-native species. The pollen taxa identified in most of the sites correspond to the main families of exotic species worldwide (Asteraceae, Fabaceae, Brassicaceae and Poaceae). Eight species were identified from the seeds found, corresponding mainly to the Asteraceae family, the most common being Hypochaeris radicata and Senecio jacobaea. Under the current climate change scenario, the pollen rain and seeds arrival in Antarctic soil, could be considered as an indirect measurement of the potential risk of the passive transport of propagules to Antarctica mediated by human beings.

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Microbial communities as indicators of hydrocarbon toxicity in soils undergoing bioremediation in Antarctica and subAntarctic Macquarie Island

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Microorganisms are ideal indicators of polar soil health. In Antarctica, they both dominate and drive ecosystem services, particularly geochemical cycling and pollutant degradation. They also respond to environmental gradients, contamination and disturbances, making them ideal, yet complex indicators of change. In Antarctica, there is a lack of site-specific toxicity data available on which robust guidelines for both contamination thresholds and remediation targets can be derived. Active bioremediation through the use of engineered biopiles are ongoing at Casey station Antarctica, while in situ bioremediation was performed at subantarctic Macquarie Island. In both cases, a lack of suitable targets has made site restoration and soil reuse problematic. Thus, the development of risk assessments that incorporate soil microbial communities and critical soil processes are essential for adequate protection of life in these regions. Through the analysis of pristine, hydrocarbon contaminated and partially remediated soils we have obtained knowledge on what key functional groups are present in a ‘healthy’ soil prior to and during remediation. We used next generation sequencing, qPCR and microfluidic qPCR to develop soil microbial community indices as indicators for both the development of ecotoxicology targets, and monitoring sites undergoing remediation. We will provide evidence that the structure and functioning of soil microbial communities can be restored to a level similar to that present prior to hydrocarbon contamination and suggest that use of microbial community indices offer a less reductive perspective on contamination, providing direct links to ecosystem function.

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Anthropogenic impact on Antarctic intertidal sediments, effects on physical-chemical parameters, macro and meiofauna

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Due to its pristine character, Antarctica is an area of special interest for the study of anthropogenic effects around Antarctic bases and its relationship with the biodiversity of the macro and meiofauna. In this work, the concentration and distribution of pollutants in intertidal sediments in the vicinity of the Captain Arturo Prat Naval Station was studied. This place has historical and current anthropogenic impacts, caused by the movement of boats and discharges of treated waters. Additionally, statistical correlations were established between the different physicochemical parameters, the macro and meiofauna.
Four physical-chemical analyzes were carried out: organic matter, total petroleum hydrocarbons, total nitrogen and free phosphorus. Additionally, sediment granulometry was characterized and macro and meiofauna organisms were identified. The bay had low concentrations of nitrogen, while the concentrations of organic matter and total petroleum hydrocarbons increase in areas with greater presence of human activity. The hydrocarbon/organic matter ratio shows to be a good indicator of environmental quality, as it increases significantly at the points of greatest impact.
Statistical analysis showed that physicochemical parameters are associated with finer soil fractions, while the biodiversity of the macro and meiofauna is negatively correlated with discharges and the presence of contaminants. Nematode and Polychaeta taxa dominate in contaminated samples, while taxa such as Ostracode and Halacaridae appear in more pristine samples. This differentiation in the species found and the statistical correlations established allow us to lay the foundations for the development of sediment quality indices on Antarctic coasts.

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Invasive non-native species likely to threaten biodiversity and ecosystems in the Antarctic Peninsula region

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Antarctica is considered to be a pristine environment relative to other continents, but it is increasingly vulnerable to invasions by marine, freshwater and terrestrial non-native species. The Antarctic Peninsula region (APR), which encompasses the Antarctic Peninsula, South Shetland Islands and South Orkney Islands, is the most invaded part of Antarctica. The risk of introduction of invasive non-native species to the APR is likely to increase with predicted increases in the intensity, diversity and distribution of human activities. Taxonomic and Antarctic experts undertook a horizon scanning to identify the species likely to present the highest risk to biodiversity and ecosystems within the APR over the next 10 years. 103 species, currently absent in the APR, were identified as relevant for review, with 13 species identified as presenting a high risk of invading. Marine invertebrates dominated the list of highest risk species, with flowering plants and terrestrial invertebrates also represented; however, vertebrate species were thought unlikely to establish in the APR within the 10-year timeframe. We recommend the further development and application of biosecurity measures by all stakeholders active in the APR, including surveillance for species such as those identified during this horizon scanning exercise, and use of this methodology across the other regions of Antarctica. Without the application of appropriate biosecurity measures, rates of introductions and invasions within the APR are likely to increase, resulting in negative consequences for the biodiversity of the whole continent, as introduced species establish and spread further due to climate change and increasing human activity.

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Persistent Organic Pollutants in Lakes of Grovnes Peninsula at Larsemann Hill Area, East Antarctica

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Over the past decades, research in Antarctica has built a new understanding of its past, present, and future. Human activities are increasing in Antarctica because of various scientific expeditions. Research on Persistent Organic Pollutants (POPs) has been carried out internationally by several countries having their permanent research station to explain the impact of an ever-increasing range of POPs in the Antarctic ecosystem. Additionally, global pollution due to various newly introduced pollutants like pesticides is on use since the past century and many factors contribute to contamination even in Antarctica.
More than 150 lakes at different islands and peninsulas are situated in Larsemann Hill, East Antarctica. It is a series of islands and rocky peninsulas which consists of two major peninsulas, four minor peninsulas, and ~ 130 near-shore islands. POPs are semi-volatile toxic compounds that resist photolytic, chemical and biological degradation, can persist in the environment for a long time. POPs were analyzed in the Lakes water samples of Grovnes peninsula, Larsemann Hills during 34th Indian Scientific Expedition to Antarctica (ISEA) in austral summer of 2014 to 2015. POP’s residue levels were found in lake water samples varied from 10.00 to 75.00 pg/mL. Presence of p,p’-DDT was detected in all different lakes & the highest concentration was found in L1E NG lake. The presence of POPs may be attributed to orographic effects, migratory birds, biomagnification and anthropogenic sources. The presence of POPs is an alarming situation and needs to be investigated further to maintain the pristine environment in Antarctica.

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Microplastics in Continental Antarctica

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Critical to understanding the possible threat of microplastics to the Antarctic ecosystem, is building up a dataset of plastic pollution in and around Antarctica. Until now, data collection has been focused within the marine environment, however, a vital data gap remains in the frozen continent. Microplastics presence in the snow of Antarctica may indicate aerial transportation of microplastics and allow estimations of the "impact zone" of operations in Antarctica. In a first of its kind study, we evaluate the presence of microplastics in relation to the local wind regime around Union Glacier whilst also assessing the presence of microplastics in unlikely remote locations, such as the Antarctic Plateau. Surface snow samples were collected at the camp edge, downwind and increasingly upwind, with control sites at remote altitude on the Antarctic Plateau and above Schanz Glacier. Samples have been analysed using Fourier Transform Infrared (FTIR) spectroscopic imaging. The fieldwork was carried out as part of the Airbnb funded "Antarctic Sabbatical"; a citizen science project where the researcher worked with Antarctic Logistics and Expeditions out of Union Glacier to train five international volunteers to collect the data and learn about plastic pollution and research. This talk will provide preliminary results from this novel dataset, offering new insight into our current understanding of microplastic pollution in the Polar Regions.

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Monitoring of freshwater lakes of Thala Hills, Enderby Land, East Antarctica

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The paper is devoted to the recent study of changes of the chemical composition of freshwater lakes and temporary ponds of Thala Hills, Enderby Land and their dependence on natural and anthropogenic factors. The region of investigation includes mainly Vecherny and Molodezshny oases.
Water sampling was carried out during seasonal Belarusian Antarctic expeditions from 2011/12 to 2017/18. The results of earlier expeditions since 60s of the XX century were used. Seven lakes and six temporary ponds located at different distance from scientific station and see shoreline has been chosen for observation. Main ions, electrical conductivity, pH as well as trace element content were included in the list of measured parameters. Heavy metals have been considered as an indicator of previous and/or current human impact. Totally during six expeditions about 40 water samples were collected and analyzed.
The mean value of measured parameters and its variability for lakes and temporary ponds are considered. It is shown that the differences in main ions content are associated with the geomorphology and, as a consequence, with the flow and processes of evaporation. In some cases, increase of heavy metals concentration in the lakes was revealed, which can be linked to anthropogenic impact including previous human activity in the oasis in late 1970s – early 1990s.
The data obtained will the basis for subsequent assessments of the vulnerability of freshwater lakes to anthropogenic impacts and climate change.

Assessment of diesel power plants air impacts in Antarctica and their trends

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The paper is devoted to assessment of air impacts of diesel generator sets which are the main sources of energy at Antarctic research stations and the main stationary sources of anthropogenic emissions in Antarctica.
Numerous factors affect emission trends: fuel consumption rates, fuel quality changes, diesel generators properties changes, diesel generators maintenance, additional emission abatement measures etc. On an example of the Vecherny oasis, Enderby Land, East Antarctica the emissions of NOx, SO2, PM10 were estimated, surface concentrations of NO2, SO2, PM10, and levels of dry deposition of PM10 were calculated for various periods of exploration of the oasis from middle 1980s to the current time using available data on diesel generator capacities in the oasis. It has been established that the area of increased maximum hourly air surface pollutants concentrations of at the receptor points and the area of increased maximum monthly deposition of PM10 over the past 30 years reduced dramatically. A comparison of these estimates with the air quality standards and background air concentrations was made.
The proposed approach will be used in subsequent studies to obtain retrospective assessments of the diesel generators environmental impacts in other Antarctic oases. The importance of information on the quality parameters of fuels used at Antarctic stations for estimating emissions is shown. This primarily relates to the sulfur content in the fuel, which affects the emissions of sulfur dioxide, as well as particulate matter.

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Local emissions and regional wildfires influence refractory black carbon observations near Palmer Station, Antarctica

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Antarctica is often regarded as the most pristine continent on Earth. However, local human activity can be significant point sources of production of contaminants, such as black carbon (BC). In May 2015, over the Austral fall season (at the beginning of the accumulation season), surface snow was sampled at eight sites along a 1.7 km transect extending from Palmer Station, Antarctica. Two additional sites were sampled on Biscoe Point, 14 km from the station. Snow samples were analyzed for refractory black carbon (rBC) with a Single Particle Soot Photometer. rBC concentrations increased with proximity to the Palmer Station, 1.2 - 16.5 µg-rBC/L-H2O, and were higher than other studies of rBC in snow, such as in the McMurdo Dry Valleys, Antarctica (MDV) and the Clean Air Sector of the South Pole Station (CAS-SP), except on the more remote Biscoe Island, which had similar background concentrations to the MDV and CAS-SP. Palmer Station is located on the SW coast of Anvers Island on the western coast of the Antarctic Peninsula. Comparison with the Navy Aerosol Analysis Prediction System model show that wildfire smoke may have reached this region during the period of the seasonal snow deposition, suggesting the increase in rBC may be a combination of local combustion of fossil fuels and regional wildfires. Although significant increases in rBC concentrations are found, rBC is limited to a few kms from the station. These initial BC measurements from the Antarctic Peninsula show similar background levels to other locations on the continent.

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Overview of risk assessment and ecotoxicology research for improved environmental protection within the Australian Antarctic Program

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A range of contaminants, including metals, fuels and oils, pose an ongoing risk to subantarctic and Antarctic marine and terrestrial environments as a result of past and current human activities. Contaminated sites associated with fuel spills, waste disposal, wastewater discharges and abandoned infrastructure are often located on rare ice-free coastal soils and in shallow nearshore marine habitats near Antarctic stations. Assessing the environmental risk at these sites and developing appropriate site specific Environmental Quality Guidelines requires consideration of the extreme physical environment and unique properties of inhabiting biota. Standard toxicity tests, using standard test species elsewhere, are not suitable for determining species sensitivities for the derivation of Environmental Quality Guidelines for Antarctica. A suite of toxicity tests using indigenous biota have been developed by the Australian Antarctic Program to assess the effects of key contaminants on Antarctic ecosystems. Traditional and novel approaches developed include single species tests, community based assessments and alterations to soil microbial processes. Information on the response and sensitivity of Antarctic biota is being used as the basis of site-specific Environmental Risk Assessments, and to derive Remediation Targets for site restoration and soil re-use for Antarctic and subantarctic regions. A summary of this work to date and how it is used in environmental decision making to inform policy and to direct operations at Australia's Antarctic stations will be presented using examples of research conducted on fuels, metals, operational chemicals and complex effluent discharges.

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Measurements matter – assessing the risk of metal contaminants in the Antarctic terrestrial environment

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Anthropogenic impact to the Antarctic environment is concentrated to ice-free coastal environments where the majority of research stations are built. These sites also act as oases for terrestrial Antarctic biodiversity because their summer temperature and the availability of substrate and water allow for the growth of endemic mosses and lichens, and colonisation of microinvertebrates. Contaminants including lead and copper can cause toxicity to Antarctic organisms. However, the bioavailability of metals is controlled by environmental factors including soil pH, organic content, redox conditions, and mineral adsorbents. Therefore, measuring metal concentrations in soils using strong extractants (e.g. concentrated acids) without accounting for environmental factors, may lead to an overestimation of risk. Diffusive gradients in thin-films (DGT) are one method of chemical sampling that accounts for local environmental chemistry by only measuring labile metal concentrations.

This study describes a field trial deploying DGTs near Casey and Wilkes stations. The presence of contamination did not inherently reflect the risk to organisms, based on comparisons with Australian and New Zealand Government (ANZG) Environmental Quality Standards. For example, soils at one site had acid-extractable concentrations of copper and lead above ANZG standards (65 and 50 mg/kg, respectively), but DGT-labile copper concentrations of 9.9 ± 0.4 µg/L and DGT-labile lead concentrations below detection limits. Other sites had low acid-extractable metal concentrations but higher DGT-labile concentrations that are known to cause toxicity to the Antarctic nematode P. murrayi. These results and the implications of using different chemical measurement techniques to assess metal contaminants risk in Antarctica are discussed.

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Eggshells identify drivers of heavy metal exposure in penguins around the Antarctic Peninsula

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The Antarctic is a remote region of increasing interest as impacts from climate change and anthropogenic influence continue to grow. Previous studies of penguin tissue suggest that heavy metal concentrations are significantly higher for penguins in colonies visited by humans than those in more remote colonies, and that this contamination may cause genotoxic mutation through erythrocytic nuclear abnormalities. Eggshells have not previously been used to study a wide spread of trace metal exposure in Antarctic penguins, but are of interest for this purpose as they indicate exposure by reproductive female adults prior to breeding. Eggshell remnants from Adélie, Gentoo, and Chinstrap penguins were collected at 24 breeding colonies around the Antarctic Peninsula during the 2006/2007 austral summer. Trace metal analysis of 28 different essential and non-essential trace metals was performed, as well as stable isotope analysis ($\delta15N$ and $\delta13C$). Results were compared by species, region, level of tourist visitation, and proximity to scientific base in order to delineate drivers of variation. Difference in species has the greatest effect on varying trace metal exposure, followed by visitation level, region and least of all, proximity to scientific base. Comparison to eggshell stable isotope values supports differences in species exposure as related to differences in trophic level. Presence of non-essential metal As was ubiquitous among samples suggesting ecosystem contamination, but Cu and Pb were widely undetectable. These results provide a framework for further study of foraging level and pollutant exposure of reproductive Antarctic penguins through easy and noninvasive methods.

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Antarctic microbes mediating mercury transformation in aquatic ecosystems

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Excess methylmercury has the feature, in addition to its high toxicity for living organisms, to be easily incorporated, bioaccumulated and biomagnified through the food web in aquatic systems. Recently, the microorganisms implicated in the transformation of mercury to methylmercury have been found much more diverse than previously thought. Antarctic regions receive atmospheric mercury through long-range transport of foreign emissions. In a context of increasing releases of heavy metals in aquatic environments and atmosphere, it is a crucial objective to elucidate the fate of mercury in Antarctic aquatic ecosystems and the role Archaea could play in mercury transformations. Hence, microbial diversity was investigated in pristine Antarctic lakes (South Shetland Islands, Antarctic, Chile) where benthic total mercury concentration was around 14 ppm. Up to 6.3% of the active community is constituted by putative methylators and a positive significant correlation was found between total mercury concentration and putative methylator relative abundance. Putative methylator Archaea Methanoregula and Methanosphaerula have been detected but did not seem active in the studied ecosystems (RNA metabarcoding VS DNA metabarcoding). By combining molecular data and a novel approach adding enriched stables isotopes of inorganic mercury and methylmercury, mercury methylation was found to overcome methylmercury demethylation activity. Metagenomic data will allow to better decipher the mercury cycle in Antarctic lakes. This investigation represents the first attempt to disclose the implication of microorganisms in the cycle and bioavailability of mercury in Antarctic aquatic systems, in which methylation appears to be the trend.

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Adelie penguins as indicators of Antarctic marine plastic pollution? Presence of phthalates in preen oil confirms anthropogenic inputs.

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Reports of marine debris and plastic contamination within Antarctic marine ecosystems are increasing in frequency and severity. Therefore, a tool for quantifying the chemical footprint of plastic-derived contaminants such as phthalates is cruical for developing and monitoring mitigation strategies. Adélie penguins (Pygoscelis adeliae) are most likely to reflect local inputs within the Antarctic and Southern Ocean as they remain south of 60oS during winter and have highly constrained foraging habitats. As such, baseline phthalate contamination in this species is likely to be an excellent bioindicator of the chemical footprint from plastic-derived contaminants to the Antarctic environment. Three common plasticizers (dimethyl phthalate (DMP), dibutyl phthalate (DBP) and bis(2-ethylhexyl)-phthalate (DEHP)) were measured in preen oil samples that were collected from live Adélie penguins (n=67) over two field seasons (2017/18 and 2018/19). Samples were taken from colonies around Australian research stations (Mawson, Davis and Casey) as well as remote locations. A robust GC-MS/MS (gas chromatography with tandem mass spectrometry) method with detection limits below current commercial analytical detection limits (ng/g wet weight) was developed to confirm the presence of phthalates and measure baseline contamination of these plasticizers to Antarctic fauna. Potential sources of plastics to the region, including research stations, were assessed by comparing the preen oil concentrations measured at different colony locations. These results provide valuable baseline information for future assessments of anthropogenic impacts of marine debris to the Antarctic environment and can be used to guide management actions to minimise future human impacts to this remote and minimally populated area.

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Establishing a baseline for POPs contamination within Antarctic marine ecosystems: using blood and preen oil samples from migratory and resident seabirds.

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There is little baseline information on persistent organic pollutants (POPs) within marine environments in Antarctica, adding to significant data gaps that exist within the Southern Hemisphere. We present baseline levels of legacy and emerging POPs using blood and preen oil from four migratory species breeding in East Antarctica (cape petrel, Antarctic petrel, southern fulmar, snow petrel (n=7 each)), compared to resident seabird species Adélie penguins (n=15). Levels of polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs) as well as newly-banned and emerging contaminants, brominated flame retardants (BFRs) were established using a robust GC-MS/MS (gas chromatography with tandem mass spectrometry) method with detection limits below those commercially available (ng/g wet weight). Contamination levels followed the pattern PCBs>OCPs>BFRs, comparable to the few reports available on Southern Hemisphere species. Exposure sources in both penguins and migratory species are mainly from long-range atmospheric transport (LRAT), yet proximity to research stations may influence exposure. While levels remain at trace concentrations, higher exposure in migratory species overall is likely related to their foraging ecology and winter migratory distances. Results from this study are the first report of POPs in seabirds local to the East Antarctic and establish seabirds as a reliable bioindicator for POPs over temporal and spatial scales within the Southern Hemisphere.

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Mercury contamination in soil caused by the human activities in Antarctica

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In order to clarify the impact of human activity to the environment in Antarctica, we analyzed the mercury concentration in surface soils around Syowa station, Skarvsnes hut and Langhovde hut. Soil samples were collected by systematic and grid sampling method (100 to 200 m) around each site in 2007. Surface soil samples were obtained which passed through 500 µm sieve and mercury concentration were directory determined by CVAAS method. The mercury concentration in soil samples fluctuates from 0.2 to 13 µg/kg, and these values were lower than the average mercury content in the Earth crust (approximately 50 µg/kg). The reason of these low mercury concentration in soil was assumed that the most of surface soil around Syowa station was decomposed granite, known as the low in mercury rock than the others. The high concentration of mercury in soil samples were observed near the station buildings. Our result indicates that the human activity in the Syowa station area may cause the environmental contamination in Antarctica.

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Quantifying bioaccumulation and biomagnification in epibenthic megafauna at McMurdo Station

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Although it is known that historic contamination of marine sediments adjacent to some Antarctic research stations (e.g., McMurdo and Casey Stations) has caused changes to marine macrofaunal communities, bioaccumulation of contaminants into epibenthic megafauna communities is relatively unknown. In this study, the concentrations of several contaminants (polycyclic aromatic hydrocarbons, PCBs, DDT, metals) were determined in 10 epibenthic megafauna species collected from two areas of intense sediment contamination and two control areas adjacent to McMurdo Station, Antarctica. McMurdo Station is an ideal location for determining the accumulation of contaminants in organisms' tissues because parts of the adjacent sea floor are considered some of the most contaminated in Antarctica. Megafauna taxa collected were generally >10 cm long and include sea stars, a sea urchin, a sea anemone, nemerteans, a bivalve, and fishes. Contaminant concentrations in the species' tissues were compared with concentrations in the sediment to infer bioaccumulation rates for sediment grazers and biomagnification rates for higher trophic levels.

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Quantifying Microplastic Contamination in the Terrestrial Environment of Signy Island, Antarctica

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Plastic pollution poses a substantial and growing environmental problem. With detrimental impacts to humans, wildlife and national economies, the ubiquity, longevity and minute size of micro- and nanoplastic particles are especially concerning. Increasingly, plastics are being detected in the most remote locations on Earth, from the bottom of the Pacific Ocean to continental Antarctica. The source of this contamination and the transport mechanisms are still unclear, however. In order to develop effective mitigation strategies, quantification of the spatial and temporal variability of environmental plastics is required. As the majority of plastic waste originates on land, investigation into the terrestrial aspect of these source-to-sink pathways is particularly relevant.

In this project, pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) techniques will be developed and implemented to qualify and quantify micro- and nanoplastic distributions in terrestrial soils and sediments. These new protocols will be utilised to probe plastic concentrations on Signy Island, Antarctica. How the BAS research station and the human presence are influencing the levels of plastic shall be studied, both spatially and temporally. Long-range transport will also be investigated through analysis of sediments from beaches and deposition zones around the island. Additionally, comparisons with the long-running beach litter survey on Signy will aid in the determination of sources and transport pathways. The resulting dataset will help further our remediation efforts, with potential policy implications.

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The Toxicity of Cu, Cd, and Pb to the Antarctic Terrestrial Nematode, Plectus murrayi

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Ice free areas make up <1% of the total land area of the Antarctic continent and are generally in coastal areas. These ice free areas are hotspots for terrestrial biodiversity and are also popular locations for scientific research facilities. As such, they are subject to human impacts, particularly soil contamination. Environmental Quality Guidelines are used to regulate soil assessment and remediation, however, Antarctic specific guidelines are currently lacking due to the limited number of test organisms and standardised toxicity tests available. This study aims to add to the limited database of terrestrial toxicity data available for metals, using established toxicity test methods for the Antarctic terrestrial nematode Plectus murrayi. Clean soils collected from Casey station (East Antarctica) were used to create porewaters, which were spiked with the metals copper, cadmium and lead, both individually and in mixtures, to make concentration series. Immobility of juvenile nematodes was assessed as a proxy for death for up to 21 days exposure. Survival decreased with increasing concentrations of copper, cadmium, and lead. Differences in toxicity were observed between the three metals, with dissolved metal concentrations of ≥63, ≥121, ≥124 µg/L causing a significant ($p<0.05$) decrease in survival relative to controls, for copper, cadmium, and lead, respectively. The 50% lethal concentrations with 95% CIs were estimated at 181 (115 – 252), 747 (471 – 1028), 1063 (634 – 1634) µg/L, for copper, cadmium, and lead, respectively. Critical effect concentrations for metals for P.murrayi will be used in the development of Antarctic specific Environmental Quality Guidelines.

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Gear loss by longline fishing vessels in the CAMLR Convention Area

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Monitoring the incidence of marine debris is important to understand trends and distribution of human impact in the Southern Ocean. In order to quantify the contribution of fishing activities on rates of debris accumulation it is beneficial to record marine debris directly from the source. Given the difficulty in determining whether terrestrially observed marine debris originates from fishing activities, monitoring gear loss rates reported by fishing vessels contributes significantly to the CCAMLR marine debris program. Lost gear has been routinely reported for every haul in CCAMLR longline fisheries catch data since 2007 and, this reporting also includes the location of each haul and so allowed the spatial distribution of lost gear to be accurately mapped. These data can be used in spatial analyses to assess the relative rates of gear loss as a function of gear type and area of operation; in particular whether there are certain areas and/conditions that are associated with elevated levels of gear loss. Monitoring and analysis of trends in fisheries -derived marine debris will increase understanding of the potential impacts such gear loss may have on the marine environment.

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Microplastic in sea ice from the rapidly warming Western Antarctic Peninsula

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Whilst the polar regions were previously thought of as pristine, we now know plastic pollution is ubiquitous, reaching both Arctic and Antarctic waters. Arctic sea ice can contain plastic particulates at levels orders of magnitudes higher than some of the most polluted regions across the globe, due to the ability of sea ice to scavenge plastic particulates, and act as a sink for plastic debris. In the Southern Ocean surrounding Antarctica, plastic has been found through the water column, in sediment and in an array of marine biota. Here, for the first time, we explore the presence of microplastic in sea ice cores collected from the Bellingshausen Sea, western Antarctic Peninsula (WAP). Microplastic fragments are identified via focal plane array FTIR analysis and characterised in terms of type, abundance and size, with fibres analysed separately. Our study adds new insight to the distribution and fate of microplastic in a region of rapid warming and decreasing sea ice extent and duration. We present results to date of this ongoing study and discuss the risks of retreating sea ice releasing scavenged microplastics to ice-reliant biota such as the keystone species of Antarctic krill, of which the WAP supports large populations.

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Anthropogenic radioisotopes (90Sr and 137Cs) in Antarctic fauna and flora

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90Sr and 137Cs are two most important anthropogenic radionuclides, which half-life is about 30 years. The main source of this isotopes were fallouts from atmospheric nuclear weapons testing in the 1950s and 1960s. Although the Antarctic is considered a pristine area, this part of globe has been also contaminated. Total input of these radionuclides was estimated as about 1% of the total emissions into the environment. Despite the fact that almost 60 years have passed since their main source, the activity of these isotopes is still measurable in the Antarctic. In order to explain this phenomenon a study was performed at King George Island in 2018. The sampling stations were located in the close vicinity of glaciers and farther away from them, beyond their direct impact. The average activity of 90Sr in water was 0.2 Bq m-3 and 0.34 Bq m-3 for 137Cs. Activity of 137Cs in sediment in Admiralty Bay was about 1 Bq kg-1, except in places close to glaciers (14 Bq kg-1). Similar trend occurred in case of soil where activity of 137Cs ranged from 0.7 to 9.4 Bq kq-1. The highest were always near the glacier. Average activity of 137Cs in plants was abour 3.4 Bq kg-1 and were similar to activity of samples collected in this area 16 years earlier. This analyses suggests that glaciers are secondary source of these isotopes, which may disrupt their transformation in the environment.

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Bioaccumulation of mercury in the first chains of Antarctic marine coastal food web (Admiralty Bay)

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Recent studies have found that the Antarctic is a sink for mercury (Hg). Atmospheric mercury depletion events stimulate Hg deposition and its incorporation in the marine food web. This metal can also be sequestrate in the snowpack along all Antarctica. Therefore, this region should be considered as a giant cold trap of mercury. The ice sheet in West Antarctica is now in a state of dynamical imbalance and the rate of ice loss is five times greater than was thought. Therefore melting ice sheet and glaciers should be considered as an important secondary mercury source for the Antarctic, which can result in an increase of Hg concentration in marine biota. The aim of the research was to identify methylmercury (MeHg) sources in Antarctica and determine their potential for accumulation in the marine trophic chain. Sampling was conducted in the Admiralty Bay in December 2018. As part of the research marine samples (water, suspended particulate matter, phyto- and zooplankton) were collected. Total mercury, methylmercury and labile Hg concentration were determined in the samples.

Mean MeHg concentration in Admiralty Bay was 15 pg/L, the highest values were measured in the vicinity of melting glaciers. MeHg in water occurred mainly in dissolved form (>70%), thus promoting the accumulation of Hg for plankton. Higher values of MeHg concentration were measured in phytoplankton (mean 204 pg/L) than in zooplankton (mean 143 pg/L). Different factors influence the accumulation of MeHg in both groups of plankton.

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Comparative analysis of mercury presence and distribution in soils within two ice-free areas of the northern Antarctic Peninsula region

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Mercury (Hg) can reach the environment through natural and human-related sources, threatening ecosystems world-wide due to its well known harmful effects. Relatively pristine terrestrial ecosystems in ice-free areas of the northern Antarctic Peninsula region are not exempt of its influence. The cold maritime climate with frequent freeze–thaw cycles in summer, parent material, geomorphological context and biological influence are important factors affecting the soil processes and development in this region. The objective of this work is to study the distribution of total Hg content in soil profiles of Fildes Peninsula (King George Island, South Shetland Islands) and Punta Cierva (Antarctic Peninsula). Samples were obtained during two field expeditions, physical and chemical analyses were carried out for the different soil horizons and multivariate factorial analysis and non-parametric tests were applied. Results show that there were no significant differences in Hg content in the upper layer of soils between both areas. However, there were significant differences in deeper horizons for soils at Punta Cierva which were related to abiotic and biotic factors influenced by periglacial processes. A strong relationship between Hg concentration and distribution existed when organic matter and certain clay minerals such as smectite content increased and binds Hg within the corresponding soil horizons. Determining Hg content in soils from remote areas such as the northern Antarctic Peninsula region provides knowledge on Hg behaviour as a global pollutant and is an important issue in the Minamata Convention on Mercury to predict potential (re)emissions or retention under a climate change scenario.

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Metal pollution and remediation at Casey Station, Antarctica – two decades of chasing heavy metals from soil through water to marine sediment

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The cleanup of the Thala Valley legacy landfill by the Australian Antarctic Division in 2003/04 represented the first large scale remediation of a contaminated site in the Australian Antarctic Territory and to date, the only one where ‘heavy metals’ such as Cu, Pb, and Zn have been the major environmental culprits.
Prior to this ‘dig and haul’ operation, much effort was devoted to measuring contamination at the landfill and in marine sediment adjacent to the site and demonstrating the impacts of pollutants on the near-shore benthic ecosystem. Chemical and biological monitoring of the benthic environment has continued in the ensuing years to evaluate changes following removal of the contaminant source.
Concurrent with monitoring, research was undertaken into ways to mitigate the risk posed by terrestrial metal contamination by in situ chemical fixation of contaminated soil using phosphate and silica treatments, and management of meltwater with permeable reactive barriers.
The way we tackle current and future metal contaminated sites in Antarctica, e.g. the abandoned station at Wilkes, Mawson Station, and other potential sites linked to future station and infrastructure upgrades, will be guided by the Thala Valley experience and the overall strategy evolved during this project.
This paper will overview the site assessment performed before and during the landfill cleanup, the marine environmental monitoring program, and metal remediation research, highlighting what we have learned and has (or hasn’t) worked well, and identifying some of the improvements, innovations and advances necessary to meet future challenges in Antarctica.

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The environmental impacts of sewage outfalls in coastal Antarctica: a case study from Davis station, East Antarctica

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An environmental impact assessment of the Davis Station sewage outfall was done to provide information to upgrade wastewater treatment facilities. The aims were: 1) Determine the properties of wastewater; 2) Assess the hydrodynamic characteristics of the marine environment; 3) Describe the nature and extent of impacts. Wastewater was high in BOD, nutrients, solids and contaminants. Levels of faecal indicator bacteria were double that of typical domestic sewage. Wastewater was lethal to local marine invertebrates at dilutions as low as 3%. Thirty sites were surveyed for sediment chemistry, sewage biomarkers, and micro and macrobiological impacts. Hydrodynamic analysis indicated that wastewater was generally dispersed in a narrow plume along the coast in the direction of the prevailing winds with some retention around the outfall. Faecal bacteria and contaminants were detected in sediments up to 1.5 km from the outfall. Dispersal rates were insufficient to prevent accumulation of contaminants in local habitats. Histopathological deformities were observed in fish, consistent with exposure to wastewater contaminants. There was evidence of impacts on macrobiological communities, and uptake of sewage into the food chain. Genes for anti-biotic resistance have been introduced into the marine environment in non-native bacteria, seawater, sediment and found in a filter feeding mollusc. Following from this study the Australian Antarctic Division is installing new facilities at Davis and other stations which will treat wastewater to the highest standards. The minimum requirements of the Madrid Protocol are insufficient to prevent environmental degradation and this situation is likely to be common at Antarctic coastal stations.

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Textile fibers in Southern Ocean ecosystems: a new contaminant of emerging concern?

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Textile fibres are ubiquitous contaminants. Their widespread occurrence has been commonly reported in plastic pollution studies, with the misleading belief that they largely derive from wear and tear of synthetic fabrics. As of today, however, an extensive characterization of their composition has never been performed. We present the results of a circumpolar survey performed in 2016/17 during the Antarctic Circumnavigation Expedition. Fibres were found in all water samples collected (n=263) with a median concentration of 1.2 fibres·l-¹. Higher concentrations were found at latitudes >60°S (1.27 fibres·l-¹) if compared to samples collected between 40°-60°S (1.09 fibres·l-¹). A sub-sample of 910 fibres were analyzed to determine their polymeric composition. µFTIR revealed that 90.4% were natural fibres of animal or plant origin. Most were cellulosic (75.9%) or wool fibres (14.5%), while only 9.6% where synthetic. The relative proportion of synthetic fibres also noticeably increased at latitudes >60°S (12.6% vs 8.6%). In addition, the presence of microfibres was also examined in 47 King Penguins fecal samples collected during the same survey in South Georgia. Microfibres were found in 77% of the samples with most fibres (88%) being of natural origin (e.g. cotton, wool) and with faeces of incubating penguins being twice as contaminated as samples from chick-rearing birds. Besides emphasizing the need for full chemical identification of these particles before classifying them as microplastics, our results demonstrate the widespread occurrence of natural and synthetic fibres in the Southern Ocean, a widespread contamination whose implications for Antarctic ecosystems are still completely unknown.

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Modulation of the freshwater diatom community structure by pollution and different climate characteristics (Antarctic vs temperate climate)

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The diatoms have a ubiquitous presence in oceans, lakes, freshwater streams and soil and they are responsible for up to 50% oxygen production. Moreover, the diatoms are a good indicator of the water quality, being very sensitive to pollution and climate changes.
In this study, we analysed the diatoms communities from East Antarctica (Larsemann Hills- 69°23'S 76°22'E- freshwater streams) and Romanian (Fagarasi Mountains - 45°36'N 24°37'E - Balea and Capra glacial lakes). The temperature changes from Antarctic environmental conditions to temperate climate conditions mimics the global warming and they could be extrapolated to predict the environmental effects of the global warming.
SEM analysed diatoms from Antarctic and Romanian locations showed differences in density and type of populations which were linked to the pollution (especially with metals) and overall environmental temperature. The diatoms population diversity and density from Romanian glacial lakes was higher compared to Antarctic freshwater streams which corroborated to a higher temperature and metal environmental pollution.
Diatoms species Achnanthes, Planothidium, Navicula, Pinnularia were common populations in Antarctic freshwater streams and Romanian glacial lakes, but Achnanthes and Pinnualaria were more abundant in glacial lakes. Diatom species Psammothidium, Luticola, Craspedostauros, Diadesmis were present only in the Antarctica, but Fragilaria, Hantzschia and Amphora were found only in Romanian glacial lakes. The specific presence of some diatoms in a particular location only could suggest an adaptation mechanism of diatoms to temperature change and metal pollution.
This research is a tribute to Teodor Gheorghe Negoita, the Romanian leader of Antarctic Station Law-Racovita during 2005-2011.

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Obtaining insight in atmospheric trace organic compound concentrations and trends in Dronning Maud Land, East Antarctica by means of long term passive and active air sampling.

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Antarctica's atmosphere is often regarded as pristine, however emissions from other continents in the southern hemisphere impact the air on Antarctica. Transport, chemical transformations and deposition are are poorly constrained in this region. Since the Austral summer of 2017 the air in Dronning Maud Land, near the Belgian research base Princess Elisabeth Station, is sampled by means of high volume sampling (HVS) where aerosol associated and gas phase compounds are collected separately. Additionally on 7 sites stretching 250km from the Antarctic plateau edge (2350m a.s.l.) to the King Baudouin Ice Shelf by the Southern Ocean, temporary sampling stations were installed. These consist of passive PUF-type samplers (Tisch, USA) for semi-volatile organic compounds and a protective shelter containing Tenax TA sorbent tubes (Markes, UK) collecting volatile organic compounds (VOC's). By exposing both for a year, a time integrated sample is obtained. With mass spectrometric analysis 70 volatile organic compounds and 16 EPA PAH's were detected on the different locations. The largest number of detected VOC's can be related with the atmospheric oxidation of aromatic components whereas primary pollutant levels are a factor 10^2-10^3 lower. This indicates the importance of the influx of foreign organic compounds which are transformed during atmospheric transport. The generated results will be combined with isotopic data gained from snow sampling on each of the 7 locations, time resolved aerosol count and properties, and back trajectory (FLEXPART) modeling to determine possible source regions of organic chemicals in East-Antarctica as well as defining atmospheric transport and transformation mechanisms.

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Polychlorinated Biphenyl Fingerprint in Clams and Fishes Winter from Quarters Bay, Antarctica

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A surprise discovery in the 1980's documented contamination of marine sediments in Winter Quarts Bay, McMurdo Station with polychlorinated biphenyls (PCB) which can exist as 209 individual congeners. The PCB fingerprint reported match Aroclor 1260, a product that was used in transformers, hydraulic fluids, fiberglass, fire retardant varnish and de-dusting agents. Study to documents bioavailability of these PCB to 10 epibenthic megafauna species were undertaken. As an expantion of this study the fingerprint of PCB in bivalve clams and fishes was used to determine the extent of bio-magnified and de-chlorination. Bivalves (e.g. clams) are used to document contamination at a specific site as they are not motile and are low in the food web. In contrast fish are motile and at the apex of the food web. By looking at the fingerprint of these congeners in sediments compared to clams and fish changes over time with the source were determined. As expected both clams and fish bio-accumulate PCB with fish exhibiting higher concentrations. Fingerprinting of the PCB in the clams and fish both document that dechlorination as reported for some temperate sediments is not occurring and that 30 years after PCB were discovered in Winter Quarters Bay they still can be attributed to Aroclor 1260.

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The Antarctic Peninsula- Canary in the Coal Mine?

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The northern Antarctic Peninsula (AP) is a hotspot for physical change around Antarctica. The stressors range from global issues (such as climate change mediated increased sea temperature, sea ice losses, ice shelf disintegration, glacier retreat, local freshening of surface waters and benthic disturbance due to ice scour) to increased anthropogenic activities (predominantly tourism, research and krill fishery). These combined stressors are having a significant impact on both the physical environment and biological communities. The AP experiences the highest human footfall anywhere in Antarctica and this is likely to increase further in the future. Our ability to detect change in the AP is typically greater than elsewhere (research station and vessel density) but monitoring is highly variable in timing and targets. This presentation aims to evaluate the key drivers of change in this area (marine and land based pollution from research and tourism, potential increase in krill fishery close to predator colonies, human interactions with marine wildlife and introductions and potentially introductions of non-native species) and assess the impacts of these predicted anthropogenic inputs on marine ecosystems. Interactions between stressors are likely to become very important, eg species at thermal limits are likely to be more vulnerable to other factors, such as direct human impacts. The data presented here forms part of the Local Drivers of Change chapter of the first Marine Ecosystem Assessment for the Southern Ocean (MEASO) and contributes to the SCAR Plastics Action Group impact assessment.

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Thirty years of marine debris in the Scotia Sea, Southern Ocean

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The incidence and impact of anthropogenic marine debris has been monitored at two sites in the Scotia Sea since the late 1980s. Between 1989 and 2019, 10,112 items of beached debris were recovered from Bird Island, South Georgia. Plastic was the most commonly collected material (97.5% by number; 89% by mass). At Signy Island, South Orkney Islands, debris items were recovered from three beaches (during the austral summer only) between 1991 and 2019. In total 1,304 items were collected, with plastic again the most commonly recovered material (84% by number; 80% by mass). The impact on wildlife has also been investigated with 1,397 Antarctic fur seals reported entangled in man-made debris since 1989. However, due in part to legislation to limit the use of plastic items, the number of entangled seals has reduced significantly since 1994. Plastic items have been found associated with seabirds at Bird Island, with Wandering and Grey-headed albatrosses the most likely to be affected. Current plastic loads seem unlikely to have an impact on birds and seals at the population level but our results nevertheless affirm that marine plastics are a major, trans-boundary animal-welfare and environmental issue. Our work highlights the prevalence of anthropogenic marine debris (particularly plastic) in the Southern Ocean and the importance of long-term monitoring efforts in cataloguing marine debris and identifying trends. It also demonstrates the urgent need for a wider understanding of the extent, scale and impact of marine debris across the entire Southern Ocean.

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Microplastics in Antarctic marine food web: evidence from penguins

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There is growing evidence that microplastic pollution (<5 mm in size) is virtually in all marine ecosystems, including in the Antarctic. Microplastics have been found in water and sediments of the Antarctic but little is known of their ingestion by higher predators. The goal of this study was to assess the occurrence of microplastics in a top predator, the gentoo penguin Pygoscelis papua, from the Antarctic region (Bird Island, South Georgia and Signy Island, South Orkney Islands) and hence evaluate the potential for microplastic transfer through Antarctic marine food webs. To achieve this, the presence of microplastics in scats (as a proof of ingestion) was investigated to assess the viability of a non-invasive approach for microplastic analyses in Antarctic penguins. A total of 80 penguin scats were collected and any microplastics they contained were extracted. A total of 20% of penguin scats from both islands contained microplastics, consisting mainly of fibers and fragments with different sizes and polymer composition (mean abundance of microplastics: 0.23 - 0.53 items individual−1 scat, comprising seven different polymers), which were lower values than those found for seabirds in other regions worldwide (Bessa et al. 2019 Sci. Rep.). No significant differences in microplastic numbers in penguin scats between the two regions were detected. These data highlight the need for further assessment of the levels of microplastics in this sensitive region of the planet, specifically studies on temporal trends and potential effects on penguins and other organisms in the Antarctic marine food web.

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Mercury pathways along the Southern Ocean food web: are they changing?

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Although Antarctica is seen as the remote and pristine continent, the levels of contaminants in the Southern Ocean have increased significantly. Mercury is one of the pollutants that is found in higher concentration than expected in the Southern Ocean waters. With this study, we aim to describe the mercury distribution along the Southern ocean food web and to evaluate if there are any variations on the mercury pathway to top predators over the last decade. To do so, we analysed sampled of several taxonomic groups from POM, crustacean, cephalopods fish and top predators, that were collected in two non-consecutive, 10 years apart, sampling years. This presentation will be focused in the path of mercury since it gets absorbed in the micro algae to the levels that it reaches in the long living top predators, using stable isotopes analyses as proxy for trophic level. We will also look into the ecological differences found between the two sampling years that would have an effect on mercury bioaccumulation pathway. Establishing the base levels of mercury in the Southern Ocean food web is crucial to better understand how this pollutant will may this fragile ecosystems.

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Microplastics in Chinstrap penguins from Antarctic Peninsula

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One of the anthropogenic pressures in the Antarctic region comes in the form of pollution, which can directly or indirectly impact the environment. Microplastics are poorly studied in the Antarctic despite being known that they can cause injuries, cumulative toxicity, increased mortality and decline in wild populations elsewhere in the World. Penguins, as they are widely spread around the Antarctic region, can be used as Antarctic bioindicators of microplastics in the marine food web. As microplastics may come via ingestion of prey, we assessed the diet of Chinstrap penguins from Antarctic Peninsula areas in breading colonies at Hannah Point and Rongé Island, analysing their scats, searching for prey and microplastics, following the methodologies developed by Bessa et al. (2019). Each scat was analysed to identify their prey (e.g. Antarctic krill), as potential source of microplastics, followed by the digestion of all the organic matter with KOH and then filtering. Beside that in every scat we analyse Antarctic Krill and measured carapace length of each one, in order to determine the diet of Chinstrap Penguins. The filters were looked under a microscope for microplastics. A total of 29 Chinstrap scats were analyzed, from which a total of 72% of scats contained potential microplastics, mainly fibers and fragments with different sizes. All potential microplastics will be analyzed (polymer identification) to confirm their synthetic origin. This work shows, for the first time, that potential microplastics is present in chinstrap penguins from Antarctic Peninsula, providing further evidence that microplastics are in Antarctic food chains.

The ubiquitous spread of plastic pollution in the Antarctic Peninsula has already reached the Antarctic spiny plunderfish stomach

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Despite the evident spread of plastic in some marine ecosystems of Antarctic Peninsula, its ingestion has hitherto not been documented. Here, we present evidence of plastic items in stomach contents of the benthic fish Harpagifer antarcticus from Fildes bay (King George Island) and we perform an assessment of potential sources considering qualitative characteristics of plastics found. Our results indicated that of the 36 processed fish, 11% of them had ingested plastic items. Fiber form constituted 100% of the ingested plastic types, with sizes ranging between 1.6 to 150 mm and dull or shiny appearance in a wide spectrum of colors (i.e. blue, red, white, black). Polymer types inferred were: polyvinylchloride, polystyrene and polyethylene. These outcomes reveal a new pathway of plastic transfer through Antarctic benthic food web and confirm strong relationship between fibers and nearshore areas with high levels of human activities. Finally, our results alert us about the threats of plastic pollution related to anthropogenic land-based operations in the Antarctic, where actions of remediation are lacking.

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Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 29

SUB-ANTARCTIC ISLANDS – SENTINELS OF CHANGE

Christel Hansen
Craig Cary, Justine Shaw, Mia Wege

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Ecological consequences of a single introduced species to the Antarctic: the invasive midge Eretmoptera murphyi on Signy Island

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The nutrient-poor soils of Antarctica are sensitive to change. Ongoing increase in anthropogenically assisted non-native species introductions means that understanding the impact of such species on these soil systems is urgent, and essential for developing future risk assessments and management actions. Through comparative baseline characterisation of vegetation, microbes, soil biochemistry, substrate composition and micro-arthropod abundance, this study explores the impacts that have resulted from the 1960s introduction of the invasive chironomid midge Eretmoptera murphyi to Signy Island in maritime Antarctica. The key finding is that where E. murphyi occurs there has been an increase in inorganic nitrogen availability within the nutrient-poor soils. Concentration of available nitrate is increased three- to five-fold relative to uncolonised soils, and that the soil ecosystem may be impacted through changes in the C:N ratio which can influence decomposition rates and the mircoarthropod community. We also measured the levels of inorganic nitrogen in soils influenced by native marine vertebrate aggregations and found the increase in nitrate availability associated with E. murphyi to be similar to that from seals. We suggest that these changes will only have greater impacts over time, potentially benefitting currently limited vascular plant populations and altering plant and invertebrate communities.

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Petrel responses to invasive species eradication on Macquarie Island

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In a changing climate pest management on islands at high latitudes takes on added importance to provide blank canvases for species that must shift their ranges. Already among the most threatened groups of birds globally owing to the impacts of invasive alien species on their breeding islands, petrels are also latitudinally range-restricted, suggesting their ranges may need to shift in the face of ongoing climate change. Understanding the responses of recovering, recolonising or newly colonising species to pest management will help clarify the extent to which petrels may be adaptable or resilient to future climate perturbations. We report the results of a three-year study to quantify short-term post-eradication responses of burrowing petrels on Australia's Macquarie Island, a Tasmanian State Reserve and World Heritage Site. The island received major conservation investment for the management of invasive predators including cats in the late 20th Century and concluding with the eradication of rabbits, rats and mice in 2011-2014. Blue Petrels, Grey Petrels, White-headed Petrels and Antarctic Prions were either extirpated or heavily impacted in terms of population size, range and breeding productivity in the 1970s. Whole-island surveys and repeat monitoring for all four species show all are present and increasing with higher breeding productivity compared with their 1970s baselines. We also recorded presence or confirmed breeding for a number of other species that are apparently recolonising or colonising for the first time.

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Lack of nocturnal warming explains the effect of in situ warming by OTC on freezing

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Antarctic vascular plants are freezing tolerant, with LT50 of -22.8°C for D. antarctica (Da) and -15.3°C for C. quitensis (Cq). The accelerated warming (3.5°C in the last century) and heat waves experienced by Maritime Antarctica, specially during summer, could cause plant cold de-acclimation making them vulnerable to stochastic frosts during the growing season. This work describes the effect of experimental in situ and laboratory warming on freezing resistance in Da and Cq. The results of in situ warming experiments using open top chambers (OTC) installed near Arctowski Station showed that after two seasons of OTC exposure, LT50 increased slightly, 2°C in Cq, at two studied sites and 2.8°C at one of the 3 studied sites for Da. A contrasting situation was observed after four growing seasons in OTCs, while Cq showed a 2°C lower LT50 in plants grown in the OTC than untreated plants, Da showed no significant differences between treatments. Therefore, this suggest that warming 3 to 4°C above average temperature would not make these plants significantly more vulnerable to freezing. This was consistent with similar antifreeze activity observed in leaf apoplastic extracts of Da grown in OTC and in open areas. These results could be associated with the fact that OTC being a passive heating system does not exert night warming. Laboratory studies in which these two species were subjected to simulated day and night warming confirm this hypothesis. Preliminary results from nocturnal in situ warming systems will be discussed

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Microplastic in Marine, Nearshore Waters of South Georgia: A study of background environmental levels of microplastic contamination which organisms are exposed to.

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Microplastics, ubiquitous in the global ocean, have even been found in remote polar environments- including Arctic snowfall and Antarctic subtidal sediment. Levels in the Southern Ocean were shown to be 100,000 times higher than predictions in some areas. The documented presence of microplastics in two resident penguin species suggests that ecologically important lower trophic levels, such as krill, and commercially important fish species, which South Georgia waters support, are also vulnerable.
This study is the first comprehensive survey of microplastics in the nearshore waters of South Georgia. Surface water samples were collected at 1km intervals around the accessible shoreline of the Thatcher Peninsula, including directly adjacent from the outflow pipes of the research station, King Edward Point (KEP). Over 50 suspected anthropogenic particles and fibres from 11 sites were confirmed to be plastic through Fournier Transmission- Infrared (FT-IR) Spectroscopy. Microplastics were present in every sample and ranged in size from 0.05mm-3mm. Preliminary results suggest that microplastic concentrations do not vary with increasing distance from KEP. In addition, two samples were collected directly from outflow pipes at KEP and Grytviken in order to determine the level of local input from anthropogenic wastewater systems. Water samples from long-term plankton monitoring sites at Rosita Harbour and Cumberland East Bay (CEB), confirm the contamination level which the keystone species, such as Euphasia superba, are exposed to in the region.
10 microplastics were found in a sample from Gull Lake, isolated from oceanographic influence, suggesting a different potential pathway for microplastic contamination: atmospheric transport.

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Sentinels of change: Can we use lichen life-history traits to predict the future of the Antarctic tundra?

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Terrestrial habitats in the Antarctic Peninsula's tundra biome are dominated by lichens and bryophytes. In order for them to maintain their role as key drivers in this pristine habitat with rapid temperature shifts, a high physiological plasticity is on demand. Previous works were based on the assumption that the width of the ecological response amplitude was linked to biogeographical distribution pattern of a species. Endemic species with narrow distribution range were considered to be highly specialised to the local climate resulting in a narrow ecological response amplitude. Generalist species, distributed across wider ranges, experience more diverse climates and therefore have wider ecological response amplitudes and physiological plasticity. Accordingly, with the climate becoming more variable in the region, we expect endemic, specialised species reach their critical stress temperature earlier than generalists, which could ultimately result in a species homogenisation with unknown effect on ecosystem services in future scenarios.
This study examines the response of photosynthesis and respiration to acute changes in temperatures for three Antarctic lichen species with different distribution patterns. While our measurements of gross photosynthesis, the total amount of fixed carbon, clearly indicate 20 degrees C as the temperature where all species experience a net carbon loss, the interpretation for the response amplitude width is not straightforward. The endemic species Usnea aurantiaco-atra shows very similar responses to the cosmopolitan species Stereocaulon alpinum indicating that other factors than acute temperature changes affect lichen viability on Livingston Island. Consequences of our results are highlighted and future research perspectives are discussed

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Biological invasions in South Africa's offshore sub-Antarctic territories

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The sub-Antarctic Prince Edward Islands (PEIs) constitute South Africa's most remote territory. Despite this, they have not been spared the fate of alien invasions. Here, we review what is known about invasions to the PEIs for terrestrial taxa (vertebrates, invertebrates, plants and microbes), freshwater taxa and marine taxa. Prince Edward Island, which has no permanent human settlement and is visited only infrequently, has significantly fewer alien species than Marion Island. the house mouse (Mus musculus), which occurs on Marion Island, can be considered the most detrimental invader to the islands; it impacts on plants, insects and seabirds, which results in changes to ecosystem functioning. The impacts of other terrestrial invaders are less well understood. At present, no invasive freshwater or marine taxa are known from the PEIs. Invasion threats to the PEIs are changing, and the amelioration of the climate of the islands may increase invasion threats to both terrestrial and marine habitats. Lessons for the sub-Antarctic region will be highlighted.

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How global change can influence the presence of the vegetation in the past and the future in Patagonia and Antarctica: An example of mosses and other species

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Southern-Patagonia has shown a great change in its weather patterns in recent years. Precipitation and winds have increased, as well as the average annual temperature. Through the analysis of the genetic diversity and structure of populations and modeling of ancestral niches, we have studied some species such as Rubus geoides, Sanionia uncinata, and other mosses species. The study was developed from the northern part of the Magallanes region in Chile from Torres del Paine to the southern Tierra del Fuego, and for mosses, it also includes some parts of maritime Antarctica. In general, the total genetic diversity for all the species was relatively low; the genetic differences among populations were moderate. Mixed ancestry in some populations, private alleles in specific sites and gene flow from specific populations were observed. Based on the observed genetic structure, results suggest the influence of reproductive biology as well as the dispersal of this species in relation to climatic aspects since the last glacial maximum. It could be also recognized the presence of a refuge. The dispersion pattern and ancestry tests suggest the importance of conserving sites whose individuals show the ability to settle in areas free of ice because they could be at risk due to the global change.

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High-frequency monitoring of stream water physicochemistry on sub-Antarctic Marion Island

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Concentrations of major ions in stream water from the Soft Plume River on sub-Antarctic Marion Island were measured. During the annual relief voyage, samples were collected daily over a 16-day period (21 April–6 May 2015) from three sites along the stream to better understand temporal and spatial variability of stream water chemistry on the island. The chemical composition of the stream is dominated by the sea salts Na^+ and Cl^-. Mean solute concentrations for Na^+ and Cl^- are 7 ± 0.58 and 12.5 ± 0.84 mg/L, respectively. The mean molar Na:Cl ratio for all samples is 0.86 ± 0.05, with a range from 0.71 to 0.99 ($n = 47$), and there is a strong, significant positive correlation between Na^+ and Cl^- concentrations ($r = 0.80$; $p < 0.001$). These values are consistent with previous studies from Marion Island and other sub-Antarctic islands. Temporal variation in ion concentrations was small. The largest detected change was a decrease in most solute concentrations that coincided with two precipitation events. This decrease was largest at the highest altitude and the shallowest site, suggesting that there was more rainfall at this location. These findings confirm the dominance of the surrounding ocean as the main source of the island's stream water chemistry and illustrate spatiotemporal patterns that provide an insight into mechanisms affecting their composition on sub-Antarctic Marion Island.

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A key to the Collembola of the Antarctic and sub-Antarctic Islands

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On sub-Antarctic islands, where species diversity is low, Collembola (springtails) are particularly important as they make up the majority of terrestrial fauna. As springtails are ubiquitous and important in sub-Antarctic ecosystems, with the number of species relatively low compared to other continental areas globally, they have been relatively well surveyed. Despite this long record of springtail collection and identification from the region, some sub-Antarctic islands have no existing keys for springtail fauna, whilst others are out-of-date. Furthermore, improved observation tools and access to genetic confirmation of species have provided new clarity on species identification. Importantly, continued introductions of novel species to sub-Antarctic islands alongside human activities have resulted in expanding established and invasive non-native springtail fauna. It is important that these new species are described and reported in updated keys to inform future identification, island conservation management and biosecurity. Understanding the indigenous diversity and the threat posed by non-indigenous springtails is essential for understanding the efficacy of current sub-Antarctic and Antarctic protected areas and their likely future value. Based on recent and long-term sampling, we discuss our up-to-date taxonomic keys and biogeographical notes for the Collembola of mainland Antarctica and several sub-Antarctic islands. In addition, we also discuss the distribution of species, non-native species and new records found.

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Diversity of the microbial communities in the rhizosphere of the endemic cushion plant from Kerguelen Islands Lyallia kerguelensis

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The sub-Antarctic islands are subject to a rapid climate change with already visible impacts on their vegetation. The Kerguelen province hosts a high richness in endemic plant species, all perennial and often long-lived, meaning these species may be particularly at risk. Here we focus on L. kerguelensis a long-lived cushion plant species strictly endemic to Kerguelen Islands. This species can be considered as keystone species, providing habitat for soil microorganisms within its rhizosphere. Conversely, the microbial communities hosted could be composed of endemic taxa that may have and may still play a role in the adaptation of this endemic plant to harsh environments and to climate change. Recently, necrotic parts were observed in L. kerguelensis cushions, which might be related to water stress since a relationship between necrosis rate and soil sodium concentration was observed. We hypothesized that the rhizomicrobiome, depending on its taxonomic composition, might influence positively or negatively plant necrosis.

Thus, our objectives were to i) determine if L. kerguelensis hosts a specific rhizomicrobiome and ii) study the potential involvement of this rhizomicrobiome in the plant vigor, by analyzing the relationship between microbial community and necrotic rate. Using metabarcoding, we analyzed bacterial and fungal communities in the rhizosphere of L. kerguelensis presenting various necrotic rates and sampled across an environmental gradient. Preliminary results suggest that fungal communities are site-specific contrary to bacteria and a relationship was observed between the relative abundance of some specific phyla and the necrotic rate. Deeper analyses are currently running to confirm these results.

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Growth and necrosis dynamics in the endemic cushion plant, Lyallia kerguelensis, across environmental conditions in Kerguelen Islands

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Kerguelen Islands, like other sub-Antarctic islands are subject to a rapid climate change consisting in enhanced mean annual temperature and decrease in rainfall. The Kerguelen province stands out as hosting a high richness in endemic plant species, all perennial and often long-lived, meaning that these species may be particularly endangered. Among them is a cushion plant strictly endemic to Kerguelen, Lyallia kerguelensis (Montiaceae). Its distribution on Kerguelen is sparse and restricted to fellfields and even “wind deserts” where the climate is particularly harsh. Furthermore, necrotic parts have been described in cushions since 1990 and may be related to water stress. Given its high patrimonial value, we aim to evaluate the response capacity of L. kerguelensis to climate change. We followed the dynamics of necrosis in plants from various populations monitored at 5 year time steps as part of the “Lyallia kerguelensis Observatory”. Populations were subject to different regional climates and local environments. Morphological traits such as vigorous and necrotic surface areas were measured by data imaging acquisition. We (i) studied changes in cushion morphology across time to determine a necrosis threshold above which the cushion fate would be death, then (ii) investigated the intra- and interpopulation dynamics of growth and necrosis in relationship to local climate and environment. The results provide a hint for the temporal scale of morphological and necrotic changes. L. kerguelensis will be a model case for the response capacity of long-lived and possibly relict endemic plant species from past eras and climates to climate change.

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Show us your beaks and we tell you what you eat: Different ecology in sympatric Antarctic benthic octopods under a climate change context

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Sympatry can lead to higher competition under climate change and other environmental pressures, particularly in South Georgia region, where the two most common octopod species, Adelieledone polymorpha and Pareledone turqueti, occur side by side. As both species' beaks are commonly found in predator's stomachs and its ecology is still poorly known due to their elusive behaviour, we studied their feeding ecology through a multidisciplinary approach combining stable isotope signatures ($\delta^{13}C$ and $\delta^{15}N$), total mercury (T-Hg) analysis and biomaterials' engineering techniques (Scanning Electron Microscopy, X-Ray Diffraction, micro-Computerized Tomography and Nanoindentation Test). An isotopic niche overlap of 95.6% was recorded for the juvenile stages of both octopod species, dropping to 19.2% in adult stages. Both species inhabit benthic ecosystems around South Georgia throughout their lifecycles ($\delta^{13}C$: −19.210 ± 1.870‰, mean ± SD for both species) but explore partially different trophic niches during adult stages ($\delta^{15}N$: 7.010 ± 0.400‰, in A. polymorpha, and 7.840 ± 0.650‰, in P. turqueti). The beaks of A. polymorpha are less dense and significantly less stiff than P. turqueti beaks. The T-Hg concentrations in the flesh of P. turqueti where higher relative to A. polymorpha (0.434 ± 0.128 µg·g-1 and 0.322 ± 0.088 µg·g-1, respectively). Overall, both octopod species exhibit similar habitats but partially different trophic niches, related to different morphology/function of the beaks. Moreover, both species presented T-Hg concentrations similar to the ones found in northern hemisphere octopod species and may increase under the present climate change context.

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Mitogenome responses to fine-scale habitat selection in three Marion Island springtail species: does the mitogenome facilitate local adaptations?

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Mitochondria are commonly referred to as the powerhouse of cells. Although mitochondria were often referred to as neutral, mitogenomes encode for proteins involved in the oxidative phosphorylation process, which provides aerobic organisms with their primary source of energy. The mitogenome is now frequently used to address fundamental ecological and evolutionary questions. In short, the functional content of mitogenomes defines evolutionary dynamics that facilitate organismal adaptations to specific environmental conditions. Springtails (Collembola) are emerging model organisms to investigate adaptive responses to environmental changes. Our study is the first to reveal the functional content of the mitogenomes of three springtail species (Isotomurus maculatus, Cryptopygus antarcticus travei, and Tullbergia bisetosa) that inhabit three different ecological niches within the soil (i.e. epigeic (surface-dwelling), hemidaphic (litter surface) or euedaphic (litter depth)). The complete mitogenome of the three species was assembled de novo and the gene boundaries were manually annotated. Comparative studies of the functional content of the mitogenomes in three study species identified candidate loci that are closely linked to springtail habitat selection. This result confirms that functional variations, in core thermal and respiratory metabolic pathways within mitochondria, play a critical role in niche specificity reported for these species.

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Warming effects in photoprotection and photo-oxidative stress markers in the two unique Antarctic vascular plants

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The Antarctic Peninsula has experienced a rapid warming in the last decades. How antarctic vascular plants (Deschampsia antarctica and Colobanthus quitensis) are responding to this accelerated warming is important to predict their success in the future warming scenario. Since redox status imbalance could be trigger under rises temperatures, we experimentally warmed a patch of Antarctic tundra using open top chambers (OTC) and evaluated its effects in a set of photoprotection and oxidative stress markers in plants growing in OTC compared to Open Areas (OA) in a natural population of the Maritime Antarctic during the growing season. In both conditions plants were able to acclimate and showed absence of photoinhibition. D. antarctica plants decreased lipid membrane damage and abscisic acid contents, as well as xanthophylls and anthocyanins in OTC compared to OA, thus suggesting a decreased activation of protective mechanisms in response to warmer temperatures. C. quitensis also showed a lower activation of their photoprotection mechanisms in OTC. Our results showed an absence of oxidative damage under rises temperatures in both species, at least under these conditions studied.
It is concluded that Antarctic vascular species are currently activating acclimation mechanisms to the prevailing warming effects and will be able to prevent, at least to some extent, photoinhibition to the photosynthetic apparatus under a climate change scenario.

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Characteristics of cryoconite holes on Ecology Glacier (maritime Antarctic)

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The most biologically diverse, active, and productive glacial communities are those associated with cryoconite holes. They form when supraglacial sediment (cryoconite) along with microorganisms absorb more solar radiation than the surrounding ice and melt into the ice. Most of the organisms in cryoconite holes are unique and highly adapted to cope with extreme cold, frequent cycles of melting and freezing, flushing of nutrients, and high UV radiation. Despite recent great interest in glacier ecosystems in the continental Antarctic, little is known about their maritime counterparts. Our study presents descriptive data on cryoconite sediments and cryoconite holes on Ecology Glacier (King George Island). Specifically, it identifies diversity and composition of microbial eukaryotes (algae, invertebrates) and prokaryotes, characterizes abiotic conditions, and describes the extent of biotic/abiotic interactions. Seventeen species of algae and cyanobacteria with biomass of 0.79 to 5.37 μg/cm³ have been found in sediments. Biomass of Bacillariophyceae was significantly higher than that of Chlorophyta and cyanobacteria. We found three species of rotifers and a glacier dwelling Acari (Nanorchestres sp.). The presence of cryophilic organisms and organic matter on glaciers may lead to a build-up of radionuclide levels on glaciers, investigated artificial radionuclides included ^{137}Cs, ^{238}Pu, $^{239+240}$Pu and ^{241}Am. Values of activity ratios in cryoconite holes suggest their yearly biological recycling, also on Ecology Glacier for more than 70 years. Overall, cryoconite holes on Ecology Glacier present unique habitats that could serve as monitoring tools to track climate-driven changes in supraglacial ecosystems in Maritime Antarctic.

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Following morphological diversity of Antarctic water bears – description of a new Dactylobiotus sp. nov. with varying egg-shell morphology and morphometry

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The challenging environments of Antarctica are represented by depauperate biodiversity, in which tardigrades (water bears) have become one of the dominant invertebrate groups. Living in various habitats, tardigrades play major roles as consumers and decomposers in the trophic networks of Antarctic terrestrial and freshwater environments; yet we still know little about their biodiversity. Tardigrades have a five segmented body and four pairs of lobopodous limbs with claws. Since tardigrades have a limited suite of taxonomic characters, eggshell morphology is considered an important trait for those groups that lay ornamented eggs. Although intraspecific variation in egg morphology is reported in some tardigrade species, it is unclear what causes morphological variation in egg morphology. KOPRI ecology team collected some tardigrade species from Lake Critical Zone Observatory (CZO) of King George Island during 2014-2015 season expedition. Among the collected several species, one species have been cultured in the laboratory rearing system. A new species Dactylobiotus sp. nov. from King George Island is distinguished from others in having morphometrically different buccal-pharyngeal apparatus and claw morphology. Culturing of Dactylobiotus sp. reveals a significant variation in the egg-shell morphology, which is recognized by differences in the number and size of the processes. Since all eggs were laid in the same stable laboratory condition, such variation is considered to be caused by epigenetic effects, and not be subject to different environmental or seasonality. These results shed new light on the identification of common tardigrade species in the maritime Antarctic.

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Evaluation of surface ablation of the Schiaparelli Glacier in response to local meteorological events using electronic Ablation Station and AWS Data

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The ablation and energy balance of the Schiaparelli Glacier were investigated for 412 days, 2017/2018. Schiaparelli glacier (Cordillera Darwin, Chile), a valley glacier with a mean annual temperature of 4.87 ºC, and 8-12 m a^{-1} of superficial melting in the ablation zone. We set a network of sensors with two automatic weather stations(AWS) and 2 electronic Ablation Stations (eAS). Ablation averaged 1.5 cm day-1, but showed seasonal variation. Radiation provided most of the glacier's melting energy, with convective flows contributing most of the rest. The results are related to local atmospheric circulation patterns. Different weather situations generate different energy estimates, with solar radiation being more important in all seasons and relatively significant convective flows in the summer and autumn seasons.

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Effect of temperature on Sanionia uncinata physiology

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The temperature on earth is rising affecting every level of life especially plants. Plants are essential for many processes like photosynthesis, water cycles, and nitrogen cycles among others. During the last years, the number of hot days in Antarctica has increased. This year the maximum temperature was recorded on Marambio station (Seymour Island) reaching an air temperature 20.75 °C, but there are other antarctic island that are experiencing a warming.
Coppermine peninsula, ASPA 112 (62°24'S; 59°30'W) is located in Robert Island, South Shetlands is an area protected because their vegetation like Deschampsia antarctica and mosses like Bryum sp; Chorisodontium aciphyllum, Bartramia patens, Syntrichia sp, Polytrichum alpinum and Sanionia uncinata among others. Since the 90 decade we have records of soil temperature, in 1995 we found that in a hot day soil could reach a maximum of 18 °C, but in 2018 we observed that temperature in the soil were plants grows reach 24.0 °C in 2019 was 29.5 and 2020 the maximum was of 30.4 °C.
When environmental conditions change, for example temperature, the plant physiology also changes with the purpose of maintain their homeostasis. S. uncinata an antarctic moss is tolerant to desiccation but there are no studies of the response to high temperatures. The objective of this work is contributing to the understanding of the physiology of S. uncinata under high temperatures in field conditions. Our results show that the antioxidant machinery of S. uncinata, specially CAT y POD to control reactive species oxygen and membrane lipoperoxidation.

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Past performance of the macrolichen Usnea aurantiaco-atra gives insights into its future behaviour in a climate warming scenario

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Usnea aurantiaco-atra is one of the most widespread and prominent macroclichens in ice-free areas of maritime Antarctica and, therefore, a key species for predicting the effects of climate change. In this experiment we linked both long-term field activity monitoring by chlorophyll a fluorescence and climate at different scales to CO2 exchange analysis in order to predict the productivity and the lichen activity at a daily level in a climate change scenario. Both field measurements and macroclimate conditions were linked with CO2 exchange analysis in order to predict the productivity and the lichen activity at a daily level in a climate change scenario. . The analysis was carried out using the longest long-term activity dataset ever published (from 2009 to 2014) in Antarctica Both predictions were carried out using generalized additive models (GAMs) and the Global Circulation Model MIROC5 of the CMIP5. Increasing temperature in the Representative Concentration Pathways (RCPs) 4.5 and 8.5 whilst maintaining present solar radiation and precipitation levels show a clear rise in productivity although lichen activity percentage remained at similar rates to nowadays. Broadly, it appears that climate change (temperature increase) would not negatively affect Antarctic-sub Antarctic species like U. aurantiaco-atra, because it is, at present, mainly photosynthetically active under suboptimal conditions as its optimum temperature is higher than the usual climate in maritime Antarctica.

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Keeping up with the neighbours: Disentangling the potential response to warming of cosmopolitan and endemic cryptogams of the maritime Antarctic

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The cryptogamic tundra in maritime Antarctica is composed of lichens and mosses of diverse phylogeographic origins. Around half of the total cryptogamic flora is made up of species that are either endemic or cosmopolitan, yet these two groups are at opposite poles of a phylogeographic classification. For cosmopolitan species the maritime Antarctic is a small part of their global distribution whereas, for the endemic species, it is their only location. The two groups have evolved under dissimilar geographic and environmental conditions and might be expected to show different adaptive potential having been selected to meet different limiting factors. For instance, in a warming scenario, it might be expected that cosmopolitan species will have adaptive advantages compared to endemics. To test this hypothesis, we investigated the response of net photosynthesis to light intensity and temperature for some of the most abundant species of lichen (Himantormia lugubris, Sphaerophorus globosus) and mosses (Andrea gainii, Sanionia uncinata) belonging to both phylogeographic categories. We used standard CO2-exchange techniques under fully controlled measurement conditions to generate response curves of net photosynthesis to light and temperature and, from these, determined the respective optima. Samples were used directly after removal from their growth sites. In addition, we recorded the microclimatic conditions when they were active in their natural habitats on Livingston Island (South Shetland Islands) using dataloggers and chlorophyll fluorescence monitoring. Although growing well under present environmental conditions, cosmopolitan species showed a strong positive response to warmer temperatures that was not detected in the endemics.

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From a local observing system of climate change to wider sub-Antarctic challenges

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Climate change has been documented in the sub-Antarctic islands along the last decades and its multiple effects are expected to deeply affect the functioning of terrestrial and marine ecosystems. This holds true for coastal marine habitats in which many species have limited regulatory abilities. Characterizing the impact of climate change on marine life implies that abiotic and biotic components of the environment be continuously recorded and monitored to interpret ecological changes, predict their potential impacts on marine life, and set up relevant conservation strategies. To this end, a long-term observing system of nearshore marine habitats was implemented in the Kerguelen Islands under the umbrella of the LTSER-France network (Zone Atelier Antarctique - ZATA) and the support of the French Polar Institute. Implemented in partnership with the National Nature Reserve of the French Southern Lands, main objectives are to establish a base line for assessing the impact of climate change on coastal marine ecosystems of the Kerguelen islands by ecological and genetic monitoring at reference sites. Using experimental and field data, ecological models are being developped to predict the response of species and populations to environmental changes around the Kerguelen Islands and beyond, in the sub-Antartic islands and the entire Southern Ocean. On-going phylogeographic studies also aim at analyzing population and species connectivity in the sub-Antarctic regions, a fundamental element for conservation actions. This can only be achieved through a dense collaborative network of national and international, complementary partners.

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Reconstructing past climate and sea ice using ice cores from the sub-Antarctic islands.

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The Antarctic and sub-Antarctic islands are uniquely located to capture changes in the globally significant circumpolar westerly winds and the Antarctic circumpolar current, key to the mixing and ventilation of the world's deep oceans. The glaciers on a number of these islands potentially contain an inimitable record of past climate, atmospheric circulation, westerly winds and pollution from this data sparse region. Here we present initial results from five new shallow (14-24 m) ice cores collected as part of the Antarctic Circumnavigation Expedition (ACE), including two Antarctic coastal domes and the first ever records from Bouvet Island, Peter 1st Island and the Balleny Islands. We present the density profiles and melt layer histories, together with ground penetrating radar, to establish the potential preservation of annual layers in the ice core records. We demonstrate their suitability to reconstruct past climate and present novel proxies for reconstructing past sea ice extent.

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The influence of landscape, climate, and history on spatial genetic patterns in keystone plants (Azorella) on sub-Antarctic islands

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The distribution of genetic variation in species is governed by factors that act differently across spatial scales. To tease these apart, it is useful to study simple ecosystems such as those on sub-Antarctic oceanic islands. We characterized spatial genetic patterns in two keystone plant species, Azorella selago on sub-Antarctic Marion Island and Azorella macquariensis on sub-Antarctic Macquarie Island. Although both islands experience a similar climate and have a similar vegetation structure, they differ significantly in topography and geological history. We generated data for 1,149 individuals from 123 sites across Marion Island and 372 individuals from 42 sites across Macquarie Island. We tested for spatial patterns in genetic diversity, and clines in different directional bearings. We also examined genetic differentiation within islands, isolation-by-distance with and without accounting for direction, and signals of demographic change. Marion Island has a distinct northwest–southeast divide, with lower genetic diversity and more sites with a signal of population expansion in the northwest. We attribute this to asymmetric seed dispersal by the dominant northwesterly winds. No apparent spatial pattern, but greater genetic diversity and differentiation between sites, was found on Macquarie Island, which may be due to the narrow length of the island in the direction of the dominant winds and longer population persistence permitted by the lack of extensive glaciation on the island. Together, our results clearly illustrate the implications of island shape and geography, and the importance of direction-dependent drivers, in shaping spatial genetic structure.

SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 30

ENVIRONMENTAL FACTORS DRIVING DIVERSITY AND COMPOSITION OF FOSSIL AND LIVING ANTARCTIC COMMUNITIES

INTERNATIONAL SCIENCE COUNCIL SCAR SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

Fernanda Quaglio, Fabiana Canini
Rowan Whittle, María Eugenia Raffi, Cristine Trevisan

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Giant pseudo-toothed birds in the Eocene of Seymour Island, Antarctica

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The James Ross Basin, at the northern tip of the Antarctic Peninsula, contains a unique Cretaceous-Tertiary sedimentary succession. The Paleogene sequence exposed in Marambio/Seymour Island has resulted highly fossiliferous, and among vertebrates, birds are one of the best represented groups. Fossil avifauna includes penguins, albatrosses, petrels, falcons, ratites, and pelagornitids, besides other doubtful records. Pelagornithidae, also known as pseudo- or bony-toothed birds, constitutes a peculiar group of extinct seabirds that lived in all continents between the latest Paleocene and early Pleistocene. We recently found a mandible belonging to a Pelagornithidae in the Submeseta II Allomember (Bartonian, middle Eocene) of the Submeseta Formation in Seymour Island. They were among the largest flying birds and are characterized by the presence of interspersed osseous pseudo-teeth of different size in the beak, and extremely light bones with a highly specialized structure adapted for pelagic soaring. The Antarctic record of pseudo-toothed birds is fragmentary and exclusively represented by isolated elements. Even so, it was possible to establish the presence of two different morpho-types based on sizes. The smaller corresponds to specimens of 3.5–4.5 m wingspan, whereas the larger were huge birds of 5–6 m wingspan. The new fossil is represented by a large dentary with latero-medially compressed denticles of three different sizes and a wide neurovascular sulcus that longitudinally runs along its lateral surface. It belonged to the second morpho-type of pelagornithids that lived in Antarctica during middle-late Eocene and reached the largest known sizes around the world.

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Signs of volcanic eruptions in an Antarctic marine benthic invertebrate

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The ability of some aquatic invertebrates to take up and accumulate trace elements has recently provided interesting results. The analysis of accumulated metal concentrations has numerous applications in the fields of biomonitoring programmes, but they can also be interesting for monitoring active volcanic areas and reconstructing past eruptive events. In this study, we analyzed the Antarctic limpet "Nacella concinna" (Strebel 1908), the most conspicuous benthic macroinvertebrate of the intertidal zone of the Antarctic Peninsula and adjacent islands. Samples were collected in Port Foster, a sea-flooded bay located in the interior of Deception Island, one of the most active volcanoes in Antarctica. The historical volcanic activity and the recent eruptions (1967, 1969, and 1970), together with the unrest episodes of 1992, 1999, and 2014–2015, categorize Deception Island as a very active volcano. The objective of this study is to evaluate whether Mg/Ca and Sr/Ca ratios measured in the shell's annual bands of the limpet "N. concinna" are reliable proxies for environmental variations, especially for those caused by volcanic activity. The combination of images obtained with optical and electronic microscope, including cathodoluminescence, allowed us to visualize and count the growth bands of the shell, and thus to determine, together with their size, the age of the limpets. We conclude that the Mg/Ca and Sr/Ca elemental ratios are not temperature-dependent, but other variables may instead influence them, and the shells do not register the volcanic activity on Deception Island.

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Habitat severity structures soil communities and aboveground-belowground linkages across a latitudinal gradient on the Antarctica Peninsula

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The Antarctic Peninsula is experiencing rapid environmental changes, making it susceptible to alterations in species diversity and distribution. However, we lack a firm understanding of soil biodiversity, including its relationship with the aboveground community and environmental parameters, some of which are rapidly changing. This strongly limits our ability to predict the consequences of environmental change for soil communities. To determine the nature and strength of aboveground-belowground linkages in influencing the soil community across the AP, we sampled soil communities at 10 sites (from 60-75°S) beneath key aboveground habitats (moss, grass, lichen, algae, and bare soil). We compared bacterial, fungal, and invertebrate diversity and abundance to soil chemistry and climatic conditions to determine the relationships between soil communities and their physical and chemical environment. While latitude, precipitation, temperature, or soil chemistry alone were not directly related to the soil community, we found that community composition and abundance varied along a "habitat severity" gradient, a composite variable that ranges from more favourable conditions of warmer temperatures with moderate precipitation and high-nutrient but low-pH soils, to sites that were either wetter or drier, often cooler, and low in nutrients. Notably, the aboveground community was more important for structuring soil communities at sites in the mid-range of habitat severity than the extremely severe or relatively less severe sites. The use of such key variables can potentially help us identify "hotspots" of soil biodiversity in order to focus conservation efforts.

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Microbial communities as indicators of anthropogenic impact in Antarctic lakes

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Fildes Peninsula (King George Island, Antarctica Peninsula) is among the Antarctic regions with the highest intensity of human activity, including six permanent scientific stations. Consequently, alterations to the environment have been noted, for example due to transportation and oil pollution. Monitoring programs in general have only been in place since the agreement of the Protocol on Environmental Protection in 1998. There is thus a lack of data concerning the region's natural state before the increased human presence. Our objective was to assess trajectories over the past century in the microbial communities of seven lakes on Fildes Peninsula. Five of these lakes are located near stations, while two control lakes are distant from the stations. We hypothesized that microbial communities in lakes near the stations are different due to the effects of human activities. Pigment diversity in water and sediments was analyzed by HPLC and modern and ancient bacterial diversity by molecular techniques. Our results show that seasonality had an effect on phytoplankton composition and biomass in modern samples due to environmental variation (in conductivity, temperature, pH and dissolved oxygen). We explored a possible increase in the delivery of anthropogenic contaminants during summer, when lakes are ice-free, as an explanation for differences in phytoplankton community composition and biomass. There were significant differences in pigment composition between sediment samples and the overlying water, confirming that lake surface sediments integrate several years of deposition. Sedimentary diversity of microorganisms and geochemical data are archives reflecting changes in past environmental conditions.

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Rates of Molecular Evolution in Antarctic and Temperate Nematodes

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Relative to nematodes from temperate climates, Antarctic nematodes have very short windows of time for growth and reproduction each year. This allows little opportunity for mutations to accumulate in the population. Thus, we expect the rates of molecular evolution to be slower than related sister taxa, since nematodes in warmer regions complete more generations in the same period of time. We used time calibrated molecular clocks generated from previous studies on phylogenetic divergence times in Panagrolaimidae to more accurately estimate rates of evolution of Antarctic nematodes and estimate dates of divergence. We also explored patterns of ice sheet advancement and retreat to test hypotheses of species divergence in response to glacial dynamics. We discuss our results in the context of mechanisms by which the Antarctic nematodes generate and maintain genetic variation and the implications of these mechanisms on their ability to respond to climate-driven changes.

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The use of next generation High Throughput Sequencing in accessing plant diversity in the South Shetlands islands

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The use of HTS has recently become a powerful tool for accessing large amounts of data, especially useful for environmental samples. Even being well established for microorganisms, its use for plants has been less applied with few studies focusing on this subject, in Antarctica its use of HTS for plant DNA is virtually non-existent. Recently our group decided to try HTS techniques in DNA metabarcoding for plant DNA present in the air, soil and snow communities on Deception and Livingstone islands. Our preliminary data suggested the presence of levels about 6x times higher of plant (Viridiplantae) diversity than previously surveyed using traditional morphological methods. Our data also suggest the presence of some invasive plants that may have been brought by humans in some very delicate ecosystems like Deception Island. In this talk we will show results for DNA metabarcoding in both islands and will discuss its use and caveats.

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Dynamics of an intense diatom bloom in the northern Antarctic Peninsula, February 2016

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Diatoms are considered the main base of the Southern Ocean food web as they are responsible for more than 85% of its annual primary production and play a crucial role in the Antarctic trophic structure and in the biogeochemical cycles. Within this context, an intense diatom bloom reaching >45 mg m–3 of chlorophyll a was registered in the northern Antarctic Peninsula (NAP) during a late summer study in February 2016. Given that nutrient concentrations and grazing activities were not identified here as limiting factors on the bloom development, the aim of this study was to evaluate the effect of water column structure (stability and upper mixed layer depth) on the phytoplankton biomass and composition in the NAP. The diatom bloom, mainly composed by the large centric Odontella weissflogii (mostly >70 µm in length), was associated with a local ocean carbon dioxide uptake that reached values greater than –60 mmol m–2 day–1. We hypothesize that the presence of a vertically large water column stability barrier, just below the pycnocline, was the main driver allowing for the development of the intense diatom bloom, particularly in the Gerlache Strait. Contrarily, a shift from diatoms to dinoflagellates (mainly Gymnodiniales <20µm) was observed associated with conditions of a highly stable thin layer. The results suggest that a large fraction of this intense diatom bloom is in fast sinking process, associated with low grazing pressure, showing a crucial role of diatoms for the efficiency of the biological carbon pump in this region.

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Defining composition and other variability of substrate: a continent-wide dataset of Antarctic rock exposures is now available (GeoMAP v.202008)

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A geological GIS dataset describing exposed bedrock and surficial geology of Antarctica has been constructed by the SCAR GeoMAP Action Group. Work started from a continent-scale, low density, attribute-poor dataset that was added to and improved through multiple iterations during 2015-2020. It involved capturing existing geological map data, refining its spatial reliability, then improving representation of glacial sequences and geomorphology. Around 83,000 polygons are unified for use at 1:250000 scale, but locally have areas with higher spatial precision, founded on a mixed chronostratigraphic- and lithostratigraphic-based classification. Feature classification and description rock and moraine polygons employs international GeoSciML data protocols to provide attribute-rich and queriable data; including bibliographic links to source maps and literature.

A new version (v.202008) will be released at the Hobart Open Science Conference, that follows a beta version made available in 2019 for comments and peer review. GeoMAP is available for webview or download (see www.scar.org/ssg/geosciences/geomap). The initiative was aimed towards continent-wide perspectives and for cross-discipline use, describing ‘known geology’ of rock and bare sediment exposures rather than ‘interpreted’ sub-ice features. Because it provides a continent-wide definition of substrate nature and composition, it should be ideal as a contextual layer for biological and ecological analysis or in models exploring environmental factors that drive diversity of Antarctic communities and their ecology.

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Coastal fjords reveal temporal patterns of lower salinity by glacial meltwater input along the western Antarctic Peninsula

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The nearshore waters of the western Antarctic Peninsula (WAP) are a region experiencing some of the fastest rates of warming, with over 87% of the marine terminating glaciers in retreat. Glacial meltwater enters the coastal ocean through fjords and embayments, altering the physical and chemical nature of the marine environment. Freshwater input can change salinity, temperature, nutrient availability, overall light availability, as well as provide greater stratification layer, favorable to phytoplankton growth. The resulting influx may influence the succession patterns of these primary producers on a seasonal or inter-annual basis. Variability in freshwater presence may favor different phytoplankton assemblages (e.g., favoring nanoflagellates over diatoms) and shift the overall seasonal timing of phytoplankton blooms. An understanding of the meltwater patterns along the WAP may help to elucidate spatial and temporal patterns seen in phytoplankton community composition and production.

In this study, sampling for conductivity, temperature, pressure, and turbidity in nearshore wasters between 62S and 65S was conducted through a citizen science project – FjordPhyto – in collaboration with the International Association of Antarctica Tour Operators vessels (IAATO). The presence of meltwater within various fjords along the western Antarctic Peninsula was analyzed, testing the hypothesis that meltwater would be observed earliest in the summer season within fjords along the northern Antarctic Peninsula, with meltwater occurrence extending southward as the season progresses. This analysis provides a preliminary glance at the variability in meltwater distribution patterns amongst fjords along the peninsula from November to March.

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Composition and diversity of microbial communities in subglacial lakes beneath Siple Coast ice streams

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Subglacial environments at the base of the Whillans and Mercer ice streams consist of water-saturated sediments and hydraulically-active lakes that effect ice dynamics. Direct access to two subglacial lakes [Whillans Subglacial Lake (SLW) and Mercer Subglacial Lake (SLM)] in this region demonstrated that active microbial communities inhabit their water columns and sediments. Higher dissolved oxygen and lower dissolved organic carbon concentrations were observed in SLM water column when compared to SLW, indicating biogeochemical differences between the lakes. Positive net water column metabolic production of reduced carbon in SLW and negative net production in SLM support this contention. The structure and composition of microbial communities in these lakes were analyzed using benthic sediment and filtered water column samples. Amplification and sequencing of the small subunit (SSU) rRNA gene indicated the majority of taxa are bacteria and archaea; however, eukaryotic SSU rRNA sequences related to unicellular ciliate protists and flagellates were detected in surficial sediments of SLM. The community structures inferred from SSU rRNA gene analysis reveals that the SLW water column was richer than SLM (1,808 vs. 619 amplicon sequence variants, respectively) and each shared more common taxa with those observed in the surficial sediments, than with each other. Sediment communities within each lake were taxonomically distinct, but shared several hundred taxa as well as similar metabolic potentials, specifically the oxidation of reduced sulfur/iron compounds and methane. One possible explanation for the greater similarities between the sediment communities is a historical linkage to ice sheet retreat and past marine incursions.

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Exploring the boundaries of microbial habitability in soil

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Microorganisms are the most ubiquitous forms of life on Earth and active microbes can be found in even the most challenging environments. As a result, it is often assumed that microbes should, over time, come to inhabit every terrestrial surface on Earth. Is this paradigm wrong? Are there terrestrial surfaces that are uninhabited? Previous work has hinted that uninhabited soil environments, without any detectable microbial activity, might exist in Antarctica. To explore this potential limit of habitability, we used a range of approaches, including cultivation dependent methods, cultivation independent genetic sequencing, and metabolic assays to explore patterns of microbial activity in Antarctic surface soils. By testing >200 soils collected along transects defined by environmental and geochemical gradients across the Shackleton Glacier Valley, we sought to confirm whether uninhabited surface soils do exist in Antarctica, and to determine what environmental factors may be limiting microbial activity. While many soils contained diverse microbial communities, we could not detect any active microbes in approximately 20% of the collected samples. Together our results suggest that microbial recruitment and survival may be limited by the unique combination of cold, dry, salty conditions experienced at inland, higher elevation sites throughout the Transantarctic Mountain. Additionally, the prevalence of fungi at many of the most challenging sites suggests that fungi may in fact be better adapted to some of the most challenging soil environments on Earth than Bacteria and Archaea.

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New ichnospecies of the medusiform burrows Gyrophyllites from the Eocene of Marambio (Seymour) Island, Antarctica

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Ichnofossils are structures produced by the activity of organisms, which modified the depositional fabric of the sedimentary rocks. Burrows, borings, and traces ichnogenera were recognized for the Eocene outcrops of Seymour Island. Here we describe the first record of Gyrophyllites usually interpreted as the result of worm-like organisms that mined the unconsolidated sediment in search for food. More than a hundred of specimens with an average diameter of 40 mm were collected from surficial levels of the Submeseta Allomember II of the Submeseta Formation that crops out in the locality DPV 13/84 of Bartonian age. They were found associated with Planolites, penguins and fish bones, in a flat sandstone surface of less than 50 mm thickness. Most of them were preserved as epirelief, although a minor number of specimens were found as complete relief, enclosed in ellipsoid concretions. They preserve a different number of non-overlapping concave petaloid lobes radiating from a shaft. Some of the specimens are preserved as a radial structure with six oval to subcircular deep lobes. In others, the petaloids are less excavated and defined, increasing the number of lobes up to nine. A third type are kidney-like structures in outline with five or less lobes. Despite these new specimens differ from all known Gyrophyllites ichnospecies, the main resemblance is with G. cristinae (Ordovician from Argentina), interpreted as the result of the colonization of a storm bed by worm-like organisms, favored by an increase of sea-floor oxygenation and the supply of fresh organic detritus.

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Teeth, legs, and ears: new evidence to fill the Paleogene record of land mammals from West Antarctica

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The current absence of terrestrial mammals in Antarctica contrast with the information from their fossil record, which indicate that this continent, played an outstanding role in mammalian evolution. Paleobiogeographical proxies suggest that West Antarctica probably functioned as an origin center for Australosphenida during the Jurassic. Also as a dispersal corridor during the Late Cretaceous?/earliest Paleogene, from Australia to South America for monotremes, and from South America to Australia for marsupials. In contrast, Antarctica was a sieve for placentals. We report here new land-mammal specimens from different levels and localities of the Eocene La Meseta and Submeseta formations in Marambio/Seymour Island: 1) A medial portion of a petrosal bone from Acantilados II Allomember at the locality IAA 1/13. 2) A mesiodistal half of a lower first premolar from the lower coquina bed of Cucullaea I Allomember at the site IAA 2/16. 3) Two teeth from the naticid bed of the Cucullaea I Allomember at the classic locality IAA 1/90. One is a fragmentary tooth with an enamel thinner than in sparnotheriodontids and astrapotherians from the same stratigraphic level. The other is a complete incisiviform of an herbivorous mammal of half the size to the incisive of Notiolofos arquinotiensis. 4) Several fragments of an upper tooth, also from the naticid beds were found in IAA 1/95. 5) A tibia from Submeseta II Allomember represents the first terrestrial mammal record in the locality DPV 13/84. These findings suggest that Eocene diversity in Antarctica was higher than previous interpretations from the fossil record.

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Who fills the gaps? Microbial communities colonising newly created aquatic habitat in the Antarctic Dry Valleys converge rapidly with pre-existing assemblages

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A commonly cited risk to Antarctic terrestrial communities from changing climate is that newly created habitat offers opportunities for enhanced species turnover. Here we investigate this paradigm by using the recent rapid rise of water level in the a perennially ice-covered Lake Vanda, Southern Victoria Land (77.52o S, 161.67o E), which is steadily creating new lake habitat. Two boundaries are steadily moving up: the soil-lake interface, and the lower ice-water boundary; and we focus on the consequences of this shift for the structure of benthic microbial mat communities, major primary producers in the system.
We used 16S rRNA gene sequence analysis to characterise microbial communities from the lake edge to 30 m depth. Replicate samples from around the seasonally unfrozen lake edge showed spatially variable bacterial communities in the most recently flooded soils, whereas within the first 2 m spatial variability declined and mat communities rapidly converged. This convergence happened within only five years of inundation. Under perennial ice cover, community composition could be related to gradients in irradiance within partially disconnected water layers characterized by distinct water chemistry. We suggest that, while creation of new substrate in Antarctic aquatic habitats initially provides an opportunity for colonisation by organisms uncommon to lake communities, at present environmental filtering is powerful enough to deliver quickly a predictable "signature" community. Only if habitat creation is accompanied by a change in environmental conditions can we expect to see persistent community shifts.

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Who cares more about chemical defences in the red seaweed Plocamium cartilagineum – the seaweed or its only grazer?

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Inter- and intraspecific interactions between organisms can either be a form of communication, environmental sensing, or defence and are often mediated by chemicals such as secondary metabolites. Sessile marine organisms such as macroalgae commonly produce chemical defences against grazers, pathogens, as well as biofoulers. Plocamium cartilagineum is a finely branched red understory alga that is common in Antarctic macroalgal forests. It supports a very high abundance of amphipods of which most are not able to feed on the heavily chemically defended P. cartilagineum except for Paradexamine fissicauda. Different P. cartilagineum individuals produce differing mixtures of halogenated secondary metabolites which are referred to as chemogroups. Around Palmer Station between 2016 and 2018 a total of 16 different chemogroups were identified. A subset of these chemogroups were used to identify whether the feeding rate of P. fissicauda differs between individuals that vary in secondary metabolite production. The same subset was used to assess differences in growth rate and reproductive output of P. fissicauda when held on a chemogroup-specific diet. These data determined whether there is a fitness cost associated with feeding on particular chemogroups and whether secondary metabolite variation impacts the grazer's feeding rate.

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Connectivity of the subtidal red seaweed Plocamium cartilagineum and how it effects the distribution of defensive secondary metabolites

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Inter- and intraspecific interactions between organisms can be a form of communication, environmental sensing, or defence, and are often mediated by chemicals like secondary metabolites. Sessile marine organisms, such as macroalgae, commonly produce chemical defences against grazers, pathogens, and biofoulers. Plocamium cartilagineum is a finely branched red understory alga that is common in Antarctic macroalgal forests. It supports a high abundance of amphipods of which most are not able to feed on their host as it is heavily chemically defended, with the exception of Paradexamine fissicauda. Different P. cartilagineum individuals produce differing mixtures of halogenated secondary metabolites which are referred to as chemogroups. Around Palmer Station, from 2016 to 2018, a total of 16 different chemogroups were identified which fit well into two haplotypes identified by the cox1 and rbcL genes. These data also suggest that chemogroups are to some extent site specific and that their occurrence has some correlation with depth. In order to determine the mechanisms driving the geographic patterns of secondary metabolites in P. cartilagineum, a variety of different approaches were taken. Transplant experiments revealed that the environment does not play a strong role in chemogroup production. Using microsatellites, preliminary analyses of multilocus genotypes have revealed that underlying patterns of genetic differentiation likely play a strong role in chemodiversity patterns, elaborating and expanding on the patterns based on single gene sequencing. Thus, findings indicate that patterns of gene flow, rather than the environment, play a larger role in the geographic distribution of chemogroups.

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Biostratigraphical and paleoecological analysis of Campanian–Maastrichtian of northern James Ross Island, Antarctic Peninsula, based on foraminifera and geochemistry data

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This study proposes a biostratigraphical and paleoenvironmental characterization of the Campanian–Maastrichtian deposits from James Ross Basin, Antarctic Peninsula, carried out in the region of The Naze, based on the analysis of foraminifera assemblages and Hg and TOC concentrations. A total of 30 benthic foraminifera taxa were identified, with 29 agglutinated ones and a single one calcareous. An association of opportunistic agglutinated foraminifers' taxa predominates in a stressful environment of neritic to upper bathyal paleobatimetry, which is in agreement with the global sea-level trend for this interval. The chronostratigraphic positioning of the interval was established by the recognition of the Gaudryina healyi Zone, corresponding to the Campanian-Maastrichtian. Campanian–Maastrichtian boundary was inferred based on the last occurrence of Trochammina ribstonensis and the first occurrence of Spiroplectammina spectabilis. Hg/TOC negative incursions at the C/M boundary suggest smaller burial or runoff in agreement with environmental conditions described as the Campanian-–Maastrichtian Boundary Event (CMBE).

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Taphonomic aspects of Late Cretaceous paleoflora from Nelson Island, South Shetlands, Antarctic Peninsula

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Paleontological studies particularly focusing on taphonomy on Nelson Island in the South Shetland Islands, are rather scarce. Here we presented the preliminary taxonomic survey and taphonomic aspects obtained during field work of the PALEOANTAR project carried out in the 2019-2020 austral summer. Specimens were collected in three fossil sites, two representing new localities (P2 and P3) at the RIP Point. P1a consist of interlayered laminae tuffaceous sandstones and siltstones with leaf impressions. Among the leaves collected Nothophagus sp., Papuacedrus sp., Dicotylophyllum elegans and undetermined ferns. The upper layer (P1b) was marked by tuffaceous sandstones with carbonized logs over 70 cm long. The elements were preferentially Northeastern oriented. The level P1c was lateral to P1b and exhibited bituminous coal lens. P1d was 30 meters above P1b and it exhibited wood fragments and possible leaf prints in tuffaceous sandstones and chloritized tuffites. P2 and P3 comprises layer of agglomerates with carbonized wood with quartz veins inside the matrix-supported conglomerate (P2) and agglomerate sheets (P3). These features are correlated to lacustrine environment for P1a and P1c. P1b, P1d, P2 and P3 could represent a change to a high energy lava flow, which could have carbonized the threes and pulverized any leaf present in this paleoenvironment. The Rip Point Flora have suggested that the environment experienced a wet meso-microthermic temperate climate with a relatively dry season similar to the conditions described for the Cretaceous Santa Marta Formation on James Ross Island, or the prevailing Mediterranean climate of Chile today.

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Wildfires in the Campanian of James Ross Island: a new macro-charcoal record for the Antarctic Peninsula

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The Cretaceous is widely regarded as a “high-fire” period in Earth’s history and extensive wildfires directly affected plant communities. These fires were frequent and widespread during this period, reaching both low and high latitudes. The James Ross Sub-Basin, especially the Santa Marta Formation bears significant palaeobotanical records from the Antarctic Peninsula, but - to our knowledge - no evidence of palaeo-wildfires were reported so far. Samples of macro-charcoal were collected in James Ross Island by the PALEOANTAR Project team during the fieldwork of the XXXV Brazilian Antarctic Operation (austral summer 2015/2016) and analysed. The material comes from the Lachman Crags Member (Santa Marta Formation) in the northeastern part of the island. It presents macroscopic features of charcoal (≥ 2.0 mm, black color and streak, silky luster). Under SEM, well-preserved homogenized cell walls can be observed. Charcoal is a direct evidence for palaeo-wildfires and the presence of homogenized cell walls confirm that the studied material was charred. In longitudinal section, tracheids show rare uniseriate or biseriate alternate pitting consisting of uniseriate pits. Rare uniseriate rays, formed by 4–7 cells with 150–187 µm height are preserved. Cross-field pitting seems to be cupressoid to taxodioid, but this feature can be easily disturbed during charring and can therefore not be used reliably for taxonomic purposes regarding woody charcoal. However, all observed characteristics point to a gymnosperm origin for these samples. The new evidence contributes to the construction of a Cretaceous palaeo-wildfire scenario in Gondwana, especially in the Antarctic Peninsula.

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Short note on the Cretaceous vertebrate fauna collected by the PALEOANTAR project in the James Ross and Vega islands, Antarctic Peninsula

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The record of fossil vertebrates in the Antarctic continent is rather scarce due to the difficult working conditions. Field work carried out by the PALEOANTAR project in the Antarctic Peninsula for several years has yielded a large number of fossils, including remains of Cretaceous vertebrates. The collecting effort has been concentrated in two islands: James Ross and Vega. Among the most important specimens recovered from James Ross is a sequence of vertebrae, propodial and autopodial elements from the base of the Lachman Crags Member (Santonian) of the Santa Marta Formation, which at the time of discovery was the oldest marine reptile recovered from Antarctica. This material further indicates a higher diversity of plesiosaur groups in the Antarctic Peninsula. Recently the Lachman Crags Member also furnished an isolated element identified as a portion of a pterodactyloid wing phalanx, the first record of this group of flying reptile in this region. Other vertebrate remains come from the upper deposits of the Santa Marta Formation and consist of isolated teeth and vertebrae of plesiosaurs, mosasaurs and sharks (e.g., Hexanchiformes, Synechodontiformes). Preliminary osteohistological analysis on fragmentary bony material revealed the presence of ankylosaurian dinosaurs. From the Vega Island, the most important specimen recovered so far is an incomplete diaphysis of a wing metacarpal IV lacking articulations of a pterodactyloid pterosaur (wingspan 4-5m) from the Snow Hill Island Formation (Maastrichtian), showing that large flying reptiles were present in this region. Systematic collecting efforts will increase the diversity the paleovertebrate fauna in the Antarctic Peninsula.

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On the employment of osteohistologic analysis on fragmentary fossil reptile bones for taxonomic purposes: an example from the James Ross Island (Antarctic Peninsula)

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Fossil vertebrates in Antarctica are scarce, mostly consisting of fragmentary material that lack anatomical features that allows taxonomic identification. However, some vertebrate groups present unique osteohistological patterns, which can result in their identification even in small fragments. To explore this possibility, a few incomplete bones collected by the PALEOANTAR project were sectioned. Among the specimens are two small elements with a crest-shaped base and top. In the first (CAV-A5), the cortical region is diagenetically worn. The medullary region is fibrolamellar, with abundant osteocyte lacunae, resorption cavities and intense reticular vascularization. There were also well-demarcated structural fibers throughout the entire primary tissue. In the second (AK-316), the secondary remodeling was intense, full of fibers and areas for the insertion of new structural fibers. There are large numbers of LAGs along the lamellar bone, and the osteons are oriented in a circular and elongated shape. The presence of structural fibers is a unique feature of Ankylosauria due to the high replacements of their primary tissue early in ontogeny. Calcium was released to ossify protective osteodermal structures in juveniles or sub-adult stages, causing an additional remodeling for the increased mechanical load. Structural fibers observed in the remodeled bone may be indicative of mechanical resistance in the Haversian tissue. The osteohistological features present in both specimens are compatible with ankylosaurid osteoderms, known by one species in this region. Although still preliminary, this study has shown that osteohistological studies can be used as an efficient tool for taxonomic identifications of fragmentary elements from Antarctica.

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Short note on shell beds (coquinas) from the northern part of the James Ross Island (Cretaceous), Antarctic Peninsula

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During the austral summer of 2015/16, the PALEOANTAR project performed fieldwork at the northern part of the James Ross Island, exploring deposits of the Lachman Crags Member, lower portion of the Santa Marta Formation (Marambio Group). Two distinct shell beds (coquinas) where identified and named based on the locality they were found as the Passo São José Shell Bed (PSJSB) and the Muro do Castelo Shell Bed (MDCSB), respectively. Based on the fossil content and the depositional structures, it can be inferred that both were formed under shallow marine conditions, with the PSJSB being deposited in a relatively deeper environment than the MDCSB. The PSJSB has an average thickness of 35 cm, with gastropods as the predominant bioclast, whose packaging is considered dense/loose. It can be classified as a calcarenite of allochemical origin. Texturally, it is a poorly sorted bioesparite, with sub-angular grains and lack mud in the matrix. This suggests a high energy depositional environment. The MDCSB is stratigraphically positioned above the PSJSB and has an irregular thickness, varying laterally from 10 cm to 48 cm. It is also classified as an allochemical calcoarenite, has a reddish color and a greater variety of bioclasts, predominantly bivalves. It presents loose packaging and levels of conglomerates. The great thickness of individual shells observed in both coquinas indicates an environment rich in nutrients and with high water temperatures, facilitating the production of CaCO3 by the organisms.

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Diversity of cyanobacteria and microalgae in coastal terrestrial ecosystems, Lützow-Holm Bay, East Antarctica

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Photosynthetic cyanobacteria and microalgae are adapted to various extreme environments (cold, dry and/or ultra-oligotrophic conditions). Continental Antarctica is an extreme environment because of its high latitude, harsh climate and ice cover. The Antarctic terrestrial ecosystem has low biological diversity. However, ice-free regions, which include only 3% area have relatively rich ecosystems dominated by cyanobacteria, microalgae, lichens, and mosses. Understanding the diversities of photosynthetic microorganisms in these environments is important because they are primary producers and their spatial distribution and diversity are changing at present. The coastal area around Syowa station (69°00’ S, 39°35’ E) in Lützow-Holm Bay, East Antarctica, contains many ice-free regions. In these regions, Japanese Antarctic Research Expedition has investigated the terrestrial ecosystems from ecological, taxonomic and physiologic points of views. Here, we conducted a sampling campaign in Langhovde (50 samples), Skarvsnes (52), Skallen (26), Ongul Island (6), Inhovde (10), Padda Island (4) and Amundsen Bay (15), during the Antarctic austral summer in 2018-2019 (163 samples). The samples were collected from different habitats: lakes, shallow wetlands ponds - streams, biological soil crusts, snow, seashores, etc. Then, cyanobacteria and microalgae diversity were identified by light microscopy together with a description of the most important environmental parameters. Samples were sorted into different groups for more detailed taxonomical and ecological analyses. In this presentation, we introduce a diversity map of photosynthetic organisms in the studied area of the East Antarctic. This research is supported by JARE-60 2018/19 and contributes to the long-term biological diversity monitoring of Antarctic terrestrial ecosystem.

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Long-term spatially-replicated data show no cost to a benefactor species in a facilitative plant-plant interaction in the sub-Antarctic

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Facilitation is defined as an interaction where one species (the benefactor) positively impacts another species (the beneficiary). However, the feedback effects of beneficiaries on benefactors are infrequently considered and are typically only documented using short-term datasets. However, a long-term repeated measures approach documenting changes in benefactor performance in relation to beneficiary cover and composition could potentially be used to more robustly examine the impact of bidirectional plant-plant interactions. Here, I use two dominant species: Azorella selago, a cushion plant species and facilitator, and a perennial grass species, Agrostis magellanica, on sub-Antarctic Marion Island as a model system, comparing individual plants over a 13-year period. I hypothesized that A. selago size and vitality would be negatively affected by A. magellanica cover, and that A. magellanica cover would be positively related to A. selago dead stem cover. I observed three main findings: 1) A. magellanica had no long-term effect on A. selago size and vitality; however, 2) the feedback effect of A. magellanica varied depending on the type of approach used and the performance measure examined, and 3) A. selago dead stem cover was not related to A. magellanica cover. Therefore, for the first time using a long-term dataset, I show that the cost of facilitation to a benefactor species may be negligible, in contrast to the majority of short-term studies. Long-term datasets may, therefore, be more practical, and possibly more robust, for assessing beneficiary feedback effects than snapshot approaches in systems where benefactors are slow-growing.

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Examining the complexity within a key plant-plant interaction: Inter-specific facilitation mediates the outcome of intra-specific interactions in the sub-Antarctic

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Where inter-specific facilitation favours the establishment of high densities of a beneficiary species, strong intra-specific competition may subsequently impede beneficiary performance and may ultimately reduce beneficiary fitness. Consequently, the negative influence of intra-specific competition could potentially outweigh the positive influence of inter-specific facilitation. Here we examine the impact of an inter-specific interaction on the outcome of intra-specific interactions (measured as beneficiary reproductive effort) within the context of plant-plant facilitation. We used the cushion-forming Azorella selago and the beneficiary grass species Agrostis magellanica on sub-Antarctic Marion Island as a model system. Experimentally reducing Agrostis density had no effect on Agrostis performance. However, the effect of Azorella on Agrostis (i.e. the inter-specific interaction) was positive, and increasingly so under more severe conditions. Moreover, observational data showed that high Agrostis densities may favour conspecific performance, because Agrostis reproduction was positively related to conspecific density, both on and away from Azorella. Finally, the effect of Agrostis density on Agrostis performance was dependent on whether the grass was growing on or away from Azorella, suggesting that the inter-specific interaction mediates the outcome of the intra-specific interaction. This research, therefore, highlights that facilitation, both within and between plant species, could matter more than intra-specific competition in some systems. More broadly, these results suggest that both positive inter- and intra-specific biotic interactions should be considered when predicting species responses to changing environmental conditions.

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Impact of Iron and Cobalamin on Phytoplankton Composition and Dimethylsulfoniopropionate Concentrations in the Amundsen and Ross Seas

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Recent studies have reported both the existence of vast groundwater systems beneath the ice sheets of Antarctica and that increased transport of warming seawater beneath coastal Antarctic glaciers has increased basal melting of the glaciers. One consequence of these findings is that coastal Antarctic seas could receive increasing non-aeolian iron inputs that could impact microbial community composition and dimethylsulfoniopropionate (DMSP) biogeochemistry. Moreover, changes in microbial community composition could alter the availability of bacterially-derived vitamin B12 (cobalamin) to B12 auxotropic phytoplankton. Previous fieldwork in the Ross Sea region has shown that both iron and cobalamin influence phytoplankton growth, taxonomic composition and DMSP levels, and can do so interactively. To further investigate the impact of iron and cobalamin on DMSP biogeochemistry, a series of six shipboard experiments involving both diatom- and Phaeocystis-dominated phytoplankton communities was conducted in the Amundsen and Ross Seas during the austral summer of 2017-18. The results of the experiments show a complex spatial pattern of responses with additions of iron alone, cobalamin alone or in tandem triggering changes in the phytoplankton community composition and DMSP concentrations. In some instances, cobalamin additions caused increases in the relative abundance of diatoms and prasinophytes irrespective of iron additions. Conversely, on occasion, iron additions resulted in an increase in cryptophyte abundance and a shift towards increasingly diatom-dominated phytoplankton communities. With respect to DMSP cycling, the most notable change was increases in dissolved DMSP, possibly reflecting changes away from Phaeocystis dominance and decreases in particulate DMSP to DMS conversion via Phaeocystis-bound DMSP lyases.

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Can we assess mesoplankton biomass of the Southern Ocean from satellites?

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The Southern Ocean is in the focus of numerous studies devoted to carbon–climate Earth system models, fishery and nature protection activities. Oceanic zooplankton is a significant contributor to carbon cycles and the main food source for fishery objects and protected whales. We present algorithms linking mesoplankton biomass (B) with surface chlorophyll concentration (Chl) and further assess integral B values for the whole Southern Ocean. We sampled three strata within the layer 0-300 m at 43 stations along the Greenwich Meridian between 34.44º S and 56.90º S. Two approaches were used to average Chl: site approach (rectangles around each sampling site) and jet approach (Chl averaged over nine rectangles bounded by eight dynamic jets; the rectangles were shifted 10° upstream). Overall, B was most strongly associated with an antecedent Chl signals. The most robust regressions linked B integrated over the whole 0-300 m layer to (1) Chl averaged three-month prior to survey and over rectangles 2º x 10º and or (2) Chl monthly averaged over rectangles shifted 10º upstream Antarctic Circumpolar Current 1-2 months prior to survey. Assessment of integral B based on found regressions gave the value of 2.49- 3.38 Gt for the whole Southern Ocean, high latitudes of the Atlantic are one order of magnitude richer in B than low latitudes between 40º N and 40º S. The presented tool may be of interest for a wide range of biologists and oceanographers; we also anticipate its benefit for carbon–climate Earth system models.

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A hierarchy of environmental factors driving composition of plankton assemblages in the Southern Ocean

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Material (43 stations, 129 samples, 163 identified taxa) was taken with a Judey net along the SR02 international transect in December 2009 synchronously with hydrological survey. At each station we sampled three strata separated by vertical gradients of temperature and salinity. We analyzed impact of major environmentals (hydrological factors, depth, surface chlorophyll, light) on structure of plankton assemblages. Novelties this study are (1) a use of surface chlorophyll as an analyzed environmental, (2) an implementation of a modern model of the Antarctic circumpolar Current (ACC) structure including hydrological fronts and dynamic jets, (3) a retrieval of the hierarchy of environmentals, individual fronts, and jets. Abundances of dominant species and total plankton abundances were distributed relatively homogenously across the ACC with maximal values in the upper mixed layer; north and south of the ACC abundances decreased. In terms of the impact on plankton assemblages, we retrieved the following hierarchy of environmentals (in descending order): hydrological factors, depth, surface productivity, light condition. Deeper insight into hydrological zonation showed a greater impact of hydrological fronts than dynamic jets. Among hydrological fronts, the Subtropical Front was the most important and followed (in descending order) by the Polar Front, the Subantarctic Front, and the Southern Boundary. Local influence of gyres and meanders on plankton assemblages was comparable to that of hydrological fronts.

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Summer phytoplankton community variability in nearshore waters of the Western Antarctic Peninsula

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The western Antarctic Peninsula (WAP) is one of the most productive regions in Antarctica. The nearshore waters, within fjords between 62-67 ºS harbor large Antarctic krill stocks that represent the main food source for higher trophic levels and, consequently overlap with breeding and feeding locations for penguin, seal and whale populations. This food web is supported by high primary productivity, however, phytoplankton studies in these waters are scarce. For this study, samples were collected during austral summers 2016-2019 from November to March, through a citizen science project – FjordPhyto – in collaboration with the International Association of Antarctica Tour Operators vessels (IAATO). Microscopy counts from six areas between 64 and 65ºS were analyzed (Cierva Cove, Wilhelmina Bay, Cuverville Island, Danco Island, Neko Harbor and Paradise Bay). Species identification and enumeration were performed by light and scanning electron microscopy and carbon biomass was estimated by cell-volume conversion. Phytoplankton abundance and carbon biomass varied up to 10 orders of magnitude. In general, phytoplankton was scarce during November, peaked during December and January (up to 9.5 × 106 cells L−1 and 1,597 µgC L−1) and decreased during February through March. Preliminary results suggest that diatoms were not predominant, while blooms of cryptophytes and prasinophytes were recurrently observed. Moreover, an intense dinoflagellate bloom was first recorded in the WAP. Most of these bloom-forming nanoflagellates do not coincide with Antarctic species. This study highlights the nearshore waters of the Danco/Graham coast as areas of high accumulation of phytoplankton biomass during austral summer.

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Phytoplankton assemblages in an Antarctic fjord: composition, diversity and productivity

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The Western Antarctic Peninsula (WAP) hosts the largest amount of glacio-marine fjords in Antarctica, which distribute meltwater to the ocean. These environments, that are sensitive to climate warming, are expected to be dominated by flagellates, in particular cryptophytes. We studied the spatial and temporal variability of specific phytoplankton composition and assessed the primary production (PP) during spring and autumn in Andvord Bay, a fjord located in central WAP and connected to the Gerlache Strait. Three main phytoplankton assemblages, that differ in their biomass, PP, and spatial and temporal distribution, were identified based on the relative biomass of the different taxa: (1) an assemblage dominated by cryptophytes, with biomass (59.2 ± 28.2 µgC L-1) and PP (1,428.4 ± 1,200.1 mgC m-2 d-1), present in the inner part of the fjord during spring; (2) an assemblage dominated by diatoms, mainly Odontella weissflogii, with biomass (40.1 ± 17.2 µgC L-1), and PP (2,529.8 ± 1,314 mgC m-2 d-1), present in the mouth of the fjord and adjacent waters of the Gerlache Strait during spring; and (3) an assemblage dominated by heterotrophic dinoflagellates, with biomass (3.5 ± 3.5 µgC L-1) and PP (160.7 ± 152.1 mgC m-2 d-1), present in the fjord and the Gerlache Strait during autumn and infrequently during spring. This study supports the notion that WAP fjord phytoplankton assemblages can be dominated by cryptophytes; however, diatoms control productivity, independent of their numerical abundance.

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Wind as a driver of fine-scale variation in plant communities

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Studies of species distributions typically focus on temperature and precipitation as climatic drivers. However, other climatic factors may also play a role in determining individual species distributions and community-level characteristics. Wind is an underexplored aspect of climate and, while the effects of extreme wind events are relatively well understood, the influence of habitual wind conditions is poorly appreciated. Here we investigate the role of wind as a driver of fine-scale variation in plant communities, using the sub-Antarctic as a study system. Data was collected in 1440 quadrats on Marion Island, measuring multiple abiotic conditions (e.g. pH, soil moisture, temperature) and plant community characteristics (species richness, vegetation cover and species composition). Using four different statistical models (GLM, GBM, GAM and GEE), we tested whether the addition of wind variables increased the accuracy of species richness, cover and composition predictions. Wind exposed areas had lower vascular plant cover than sheltered areas. Additionally, wind had a significant effect on species composition, but not on species richness. This suggests that wind-tolerant species replace those that cannot survive stronger wind conditions, thereby maintaining a similar species richness across the wind gradient. There is a growing availability of wind data at coarse scales, but these results suggest that variation in winds at fine-scales requires greater attention during ecological studies. Given the current changes in global wind patterns, it is potentially important to understand how wind affects species and communities in order to predict how vegetation will respond to future changes in climate.

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Food Web Structure and Community Composition of 13 Lakes and Ponds Across the Antarctic Peninsula

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Antarctic Peninsula has been rapidly warming and consequently terrestrial aquatic ecosystems change in abundance and surface cover as well as ecosystem structure and function. Therefore, comparative studies of aquatic ecosystems across large latitudinal gradients is to be useful for better understanding the changes in these ecosystems as well as for more reliable predictions under changing climate. We have sampled thirteen lakes and ponds across the Antarctic Peninsula during Turkish Antarctic Expeditions in 2018 and 2019 seasons. The lakes and ponds are located in Ardley, Robert, Livingstone, Galindez and Horseshoe Islands covering a latitudinal gradient over 800 km. We conducted snap-shot samplings for water chemistry (nutrients and trace metals), biota (pigments, plankton, epiphytic diatoms and macroinvertebrates) and stable isotopes (N15, C13). The pigment compositions were assessed using HPLC. Epiphytic diatoms were identified and counted using light and electron scanning microscopy. These lakes had a large variation in nutrient concentrations (0.04 - 55.09 micM PO4 and 0.11 - 39.55 micM NO3 + NO2) and conductivity (30-735 micS). The composition of pigments in the water column and epiphytic diatoms had also a significant variation across the lakes. These changes were predominantly associated with salinity and conductivity gradients across the lakes. Overall, the patterns mostly reflected the transport from the sea mediated through the activities of animals (seals and penguins).

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Diatom stratigraphy of a periglacial lake in Robert Island, Antarctic Peninsula

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Understanding past changes in climate and environment as well as their effects on the biota and ecosystems is crucial for effective prediction of future climate change and management of fragile ecosystems. Lakes of the Antarctic Peninsula are facing dramatic changes and paleoecological studies enable us to better understand and quantify these changes. For the study presented here, a lake sediment core of 20 cm length from the Robert Island (59°40'6.10"W 62°23'4.77"S) in the Antarctic Peninsula was analyzed. To assess the community shifts, sediment core was sliced into 2 cm intervals and permanent diatoms slides were prepared and counted up to 400 frustules for each interval. Species identifications were completed via light microscopy and scanning electron microscopy. We observed that most dominant species in the sediment samples are from Planothidium, Psammothidium and Nitzschia genera. Planothidium australe constituted 14% of the diatoms in the top 0-2 cms of the sediment core and Planothidium reneii constituted 18% of the diatoms in the top 18-20 cms of the sediment core. Planothidium spp are known to be common in small alkaline freshwater lakes of the region, indicating the high pH levels throughout the lake history covered by the analyzed sediment core. The change in the diatom communities and biogeochemical characteristics of the sediment core will be presented to infer the recent past of the lake and its catchment.

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The interplay of bacterioplankton and phytoplankton communities in the course of summer phytoplankton bloom in Argentine islands region

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The long-term marine monitoring program was launched at Ukrainian Vernadsky Antarctic Station to study the state of marine foodweb, in particular the interplay of phytoplankton and bacterioplankton communities in the course of phytoplankton bloom. The samples were collected at 2 depths - surface and deep chlorophyll maximum (DCM) at 6 stations near Galindez island, under the differential influence of meltwater run-off, during summer bloom in February 2019. Bacillariophyceae (60%) and Dinophyceae (24%) dominated phytoplankton community. The representatives of Bacillariophyceae were the most abundant at DCM comprising 73% compared to 17% at surface, at the contrast Prymnesiophyceae constituted 40% at the surface and 10% at DCM. Both surface and DCM bacterioplankton communities were characterized by the dominance of Rhodobacteraceae (65% and 44% respectively), Nitrincolaceae (10% and 21%) and Flavobacteriaceae (14% and 12%) known to be the first responders to algal bloom and benefiting from phytoplankton exudates. At the genus level Sulfitobacter, previously shown to be associated with diatoms, were the most abundant at both surface (60%) and DCM (40%). Significant proportion of bacterioplankton community functional repertoire included MetaCyc pathways involved in phytoplankton exudates' breakdown (secondary metabolite degradation, amine and polyamine degradation, carboxylate and carbohydrate degradation, sulfur and nitrogen compound metabolism). The results obtained indicate the complex interplay existing between phytoplankton and bacterioplankton in the course of phytoplankton bloom and highlight the importance of further investigation in this field, as it is one the primary factors influencing the nutrient flux and shaping the foodweb.

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A new neopterygian fish from the Late Jurassic Ameghino (=Nordenskjöld) Formation

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A new Jurassic neopterygian fish is presented on the basis of an almost complete specimen from the early Tithonian (Late Jurassic) Ameghino (=Nordenskjöld) Formation in the Argentine Antarctic Sector (Antarctic Peninsula). The specimen was recovered during the 2019/2020 Antarctic Summer field. Analysis of the new material suggests this is a new species of Dapediiformes –deep-bodied neopterygian fishes–. Dapediids as a whole are yet poorly sampled in formal phylogenetic analyses but to date, they are considered as stem-holostean fishes or the sister group of ginglymodians [Semionotiformes + Lepisosteiformes]. Moreover, the establishment of apomorphic characters for the members of the group is difficult. The specimen presented herein shares some similarities with the genus Dapedium (e.g., ellipsoidal to circular body outline, a seam-like dorsal fin, pectoral fin placed high in the body, roughly rectangular scales with a smooth caudal margin, skull bones heavily ornamented with tubercles). Besides its importance as the first Dapediiformes described from Gondwana continents, this specimen adds information relative to the anatomy of this fish group, their diversity, ecology, and paleobiogeography. Furthermore, the study of this fossil will increase the understanding of dapediids anatomy and phylogenetic relationships among neopterygians.

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Antarctic Middle-Late Mesozoic marine fossil-bearing units: new reports and future perspectives from Argentine paleontological explorations

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Scientific activity in the Argentine Antarctic Sector has been conducted by the Instituto Antártico Argentino (IAA) since 1951. The Vertebrate Paleontology Research Group (VPRG) comprises several disciplines within the study of vertebrates and incorporates researchers and technicians from different Argentinian institutions. The main objectives of this group are the prospection, collection, and study of fossil vertebrates recovered during the Antarctic Summer field season. The Jurassic in Antarctica is still little explored, even though it represents a key moment for understanding the evolutionary history of certain fish groups. In light of the Jurassic outcrops occurring in Antarctica since 2015 the VPRG, has been exploring some areas with a strong focus on the recovery of fossil fishes. Jurassic marine fishes were known from the Ameghino Formation (=Nordenskjöld) and the Hauberg Mountains Formation. Our preliminary results show that the taxonomic diversity of fishes from the Ameghino Formation is greater than what had been previously reported. Additionally, abundant bromalites with fish remains content have been recovered, as well as other vertebrates and invertebrates previously undescribed at the formation. The studies of the fish material and bromalites might provide information on anatomy, taxonomy, phylogeny, paleoecology, paleobiology and morphological disparity of the taxa. These data are useful to improve the understanding of the Jurassic gap in the evolutionary history of the major clades of fishes in the Southern Hemisphere.

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Geology and palaeontology of the Marine Maastrichtian of the James Ross Basin, Antarctica: New multi proxy approach

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During the last summer 2020 field trip carried out under the Argentine Antarctic Program (IAA-DNA), new geological and palaeontological data of the Maastrichtian López de Bertodano Formation (Upper Cretaceous), James Ross Basin was recovered. This transgressive/regressive sequence is well exposed in the Sandwich Bluff Member of Vega Island and in the southern part of Seymour (Marambio) Island. The aim of this study is to compare both areas, in order to evaluate in detail their potential palaeoecological differences. We elaborate detail sedimentological logs and exhume new fossil material of vertebrates, invertebrates and plants. Fossil vertebrates belong to neognathae birds, chondrichthyes and osteichthyes fishes and marine reptiles. In comparison with Seymour Island fossil vertebrates at Sandwich Bluff Member were found isolated or incomplete, and the fossil association of marine reptiles is characterized by less abundance of mosasaurs vs plesiosaurs. The invertebrate fauna is less abundant and diverse. Few isolated bivalves were recovered and the presence of abundant and well preserved leaves and logs suggest a stressful environment. Vega fossil assemblages indicate marginal near-shore environments under tidal-influence characterized by an impoverished of invertebrate. In terms of diversity and taphonomy, the fossil record of marine reptiles in this area could be indicating that they would not have actively inhabited these environments, and that the incomplete remains found correspond to fragments of skeletons dragged towards the coast. The sedimentological data shows that upper beds of the Sandwich Bluff Member consist of siltstone to fine-grained sandstone deposits.

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Myco- and photobiont associations in crustose lichens in the McMurdo Dry Valleys (Antarctica) reveal high differentiation along an elevational gradient

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The climate conditions of the McMurdo Dry Valleys (MDV, 78° S) are characterized by low temperatures and low precipitation. The annual mean temperatures at the valley bottoms range from -30 °C to -15 °C and decrease with elevation. Precipitation occurs mostly in form of snow. Liquid water is rare and represents the primary limitation to biological activity. Snow delivered off the polar plateau by drainage winds, dew and humidity provided by clouds and fog are important water sources for rock inhibiting lichens. In addition, the combination of the extremely low humidity and drying caused by foehn winds, confined to lower areas of the valleys, with colder and moister air at higher altitudes creates improved water availability with elevations.

We investigated the diversity and interaction specificity of myco-/photobiont associations of a total of 232 crustose lichen specimens, collected along an elevational gradient (171-959 m a.s.l.) within the MDV. Elevation, positively associated with water availability, turned out to be the key factor explaining most of the distribution patterns of the mycobionts. Pairwise comparisons showed Lecidea cancriformisand Rhizoplaca macleanii to be significantly more common at higher, and Carbonea vorticosa and Lecidea polypycnidophora at lower, elevations. Lichen photobionts were dominated by the globally distributed Trebouxia OTU Tr_A02 which occurred at all habitats. Network specialization resulting from mycobiont-photobiont bipartite network structure varied with elevation and associated abiotic factors.

Along an elevational gradient, the spatial distribution, diversity and genetic variability of the lichen symbionts appear to be mainly influenced by improved water relations at higher altitudes.

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Understanding the microbiome diversity through a combination of remote sensing and close-range field observation techniques in the Sør Rondane Mountains, East Antarctica

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The sparse ice-free regions of Antarctica are the coldest arid deserts on Earth. Yet, ice-free soils harbor substantial and diverse microbial communities that can vary significantly between the regions and the micro-climatic conditions. The factors responsible for driving the microbial diversity and community structure in inland nunataks of East Antarctica, like the Sør Rondane Mountains, are still poorly understood. Within the BELSPO MICROBIAN project, three sampling campaigns took place in a 70 km radius around the Belgian Princess Elisabeth Station during the Austral summers of 2018, 2019 and 2020, resulting in the biggest sampling effort for microbial analysis in the region. Samples ranged from different kind of barren bedrock to substrates covered by biofilms and well-developed biological soil crusts consisting of lichens, mosses and cyanobacterial/microalgal mats. In this study, long-term microenvironmental monitoring data show that temperature and soil humidity regimes vary with the elevation, slope, aspect, wind exposure and daily irradiance regimes of the surveyed nunataks. Bacterial and eukaryotic diversity were assessed by amplicon sequencing targeting 16S and 18S regions of the rRNA genes with the Illumina MiSeq platform (2x300 bp). Preliminary multivariate analysis indicate that habitat characteristics derived from remote sensing and data loggers give important insights about the distribution of bacteria, cyanobacteria and eukaryotes in these unique environments. Further analyses are ongoing on chemical characterization of the soils and on potential biotic interactions to better understand the terrestrial microbial ecology of Antarctic ice-free regions.

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Fatty acid trophic transfer from Antarctic algae to the benthic amphipod Gondogeneia antarctica

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The shallow coastal benthos (between 5- 40 m) of the Western Antarctic Peninsula supports dense macroalgal forests, often dominated by large chemically defended brown macroalgae. Macroalgae provide cover for abundant amphipod communities that include carnivores, omnivores, and herbivores, which primarily consume diatoms and other chemically undefended macroalgae. Some of these chemically defended macroalgae become more palatable within a few weeks of death and the contribution of these dead macroalgae to amphipod diets is unknown. The trophic dynamics between amphipods and macroalgae are difficult to observe directly, making the use of biomarkers such as fatty acids ideal if controlled feeding assays are used to quantify how amphipods incorporate the fatty acid signatures of their algal diets into their tissues. We performed a feeding trial with Gondogeneia antarctica to generate a fatty acid 'resource library' of known diets which we compared with the fatty acids of G. antarctica collected in the wild. We maintained G. antarctica on one of four possible algal diets, representing a palatable macroalga (Palmaria decipiens), benthic diatoms, or one of the two freeze-killed chemically defended macroalgae (Desmarestia anceps or Himantothallus grandifolius). After nine weeks, amphipod fatty acid signatures reflected their diet treatments with those amphipods maintained on diatoms having fatty acid profiles most similar to wild amphipods, suggesting that diatoms make up the majority but not the entirety of the diets of G. antarctica in situ.

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Exploring the Streptophyta at Deception island (Antarctica, South Shetlands) using metabarcoding of environmental soil DNA

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Antarctica vegetation is composed by only two native angiosperms and about 142 bryophyte species. The Deception Island shows about 50% of all moss diversity of Antarctica and 18 species that doesn't occur anywhere else in the continent. Environmental DNA or eDNA metabarcoding has the potential to detect and classify genetic molecules of species present in environmental samples such as sediment, water, soil, air, and feces. This tool was used by the first time in Antarctica to detect plant DNA in soil to reveal taxa non detectable through traditional surveys. In this study we aimed to use NGS to investigate community's diversity of Streptophyta (Viridiplantae) present in soil samples in two different sites in Deception Island, one inside of a protected area (Crater Lake) and one outside (Whalers Bay). A total of 39 taxa were found in the soil. Crater Lake samples presented seven Bryophyta, one Marchantiophyta, one Monilophyta and 14 Magnoliophyta; in Whalers Bay, we found five Bryophyta, two Monilophyta and 22 Magnoliophyta. The more abundant species was Imbribryum blandum, never cited to Antarctica before, occurring as South as the subantarctic Campbell Island, followed by Sanionia uncianata, the most common moss species in Antarctica. However, we found 32 species not previously cited to Antarctica, most of them (29) vascular plants. The protected area showed 25% less taxa than non protected area in Deception of total the taxa. This could be an indication that protected areas are less disturbed by human activities and potential introduction of non native plant DNA.

1329

Diversity, biogeography and potential parasite-host interactions of aquatic fungi in (sub-)polar lakes

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Towards the poles, freshwater biota are increasingly dominated by microorganisms, many of which perform critical ecosystem functions. In addition, Antarctic freshwater foodwebs are regarded as truncated, because many clades, such as large metazoan grazers, are absent while microbial heterotrophs are important components. Nevertheless, little is known about the biogeographic distribution or the trophic status of many of these heterotrophic microeukaryotes.

We studied the biodiversity of microbial eukaryotes, focusing on fungi in (Sub)Antarctic lake benthos using high-throughput sequencing of the ITS region and 18S rRNA gene and compared the patterns with similar data from the Arctic to study their biogeography. Our results show that polar lakes harbour a diverse pool of fungi, dominated by Cryptomycota and Chytridiomycota, as well as yeast-like Ascomycota and Basidiomycota and a relatively large proportion of unknown diversity. Additionally, several taxa were restricted to the Southern Hemisphere. Local OTU-richness in the Southern Hemisphere lakes was significantly lower than in the Arctic, and fungal communities were considerably differentiated between the biogeographical regions. Co-occurrence network inferences revealed that Chytridiomycota and Cryptomycota OTUs were significantly overrepresented, and their abundances were strongly and positively correlated with OTUs belonging to Bacillariophyta, Chrysophyceae-Synurophyceae and Dinoflagellata, suggesting that these taxa may serve as potential hosts. Combined, we show that poorly understood or unknown taxonomic groups among the Cryptomycota and Chytridiomycota account for a large proportion of polar and subpolar aquatic fungal diversity. Our results suggest that these predominantly parasitic groups may have an underestimated role in the carbon and nutrient cycling of polar lakes.

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Beta-diversity of an Antarctic rocky subtidal community is associated with glacier meltdown processes

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The Western Antarctic Peninsula (WAP) shows one of the fastest responses to climate change on Earth. Glacier meltdown—leading to increased seawater turbidity and decreased temperature and salinity—is one of the largest environmental responses with larger implications of anthropogenic impacts in the WAP. The consequences of this process for fundamental attributes of biodiversity, such as beta-diversity, are still not well understood. Here, we assess the beta-diversity of a species-rich marine subtidal macrobenthic community (consumers and primary producers) across two abiotic environmental gradients defined by the distance from a glacier (several km) and depth (down to 20 m) in Fildes Bay, King George Island. The analysis of spatially extensive records of seawater turbidity, high-frequency temperature and salinity data, and suction dredge samples of macrobenthic organisms revealed non-linear and functional group-dependent associations between beta-diversity, glacier influence, and depth. Species richness and Shannon's diversity of consumers significantly decreased in the nearby of glacier relative to reference sites. The number of consumer species also increased with depth across the bay. Moreover, the spatial variation in community structure of consumers and primary producers depended on both glacier distance and depth. These results suggest that glacier melting can have significant effects on diversity and community structure. Therefore, the observed acceleration of glacier meltdown may have major consequences for local biodiversity in this ecosystem.

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The influence of the Polar Front on vertical mesoplankton migrations: a case study from the Drake Passage

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Diurnal and seasonal vertical migrations of zooplankton represent a widespread phenomenon occurring both in marine and freshwater environments. However, they are believed to be absent or insignificant during summer in subpolar and polar areas such as the Southern Ocean. This viewpoint has been accepted in numerous studies of vertical distribution of net mesoplankton. However, the data obtained from various hydrological zones are often put in a common data pool, so trends within each of these zones can be masked. The hydrological fronts greatly influence plankton composition and its spatial and temporal distribution. Here we test the hypothesis that hydrological fronts do influence the patterns of diurnal vertical migrations of mesoplankton. We analyzed diurnal dynamics of abundance, biomass and diversity of mesoplankton at differnet depths sampled in four cruises in the Drake Passage during spring and summer in 2008-2011. During all these cruises we observed a prominent Polar Front (PF), which provided statistically representative division of stations on both sides of it. We analyzed material of 85 day-and-night stations and found that diurnal and seasonal migrations significantly differ south and north of the PF. We present and analyze observed differences in diurnal and seasonal dynamics of the community integral parameters (abundance, biomass, diversity) and individual dominant taxa.

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The nitrate-to-dissolved-iron ratio in West Antarctica coastal waters

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Diatoms experience iron stress at high nitrate-to-dissolved-iron ratios in high-nutrient low-chlorophyll (HNLC) ocean provinces. In Antarctic coastal waters, dissolved iron enrichment is found near ice shelves, at the sea-ice edge, during spring blooms, or at oceanic fronts. We expect these regions or events to be enriched in diatoms. In West Antarctica, dissolved iron has been identified as the limiting growth factor for phytoplankton growth. The literature reports concentrations varying by 2 orders of magnitude while the nitrate-to-dissolved-iron ratio varies by 3 orders of magnitude. This ratio is mainly controlled by the dissolved iron concentration. Waters with lowest ratios are found in the western Antarctic Peninsula coastal and shelf waters, a region known for abundant and diverse diatom species. In contrast, waters in the Amundsen and Ross Seas have the highest ratios, regions where Phaeocystis antarctica blooms abound. Based on detailed sampling in Antarctic fjords, we were able to estimate pseudo-uptake rates for diatoms and flagellates in the field which indicate that diatom growth increases the nitrate-to-dissolved-iron ratio by efficiently stripping iron from surface waters. However, as diatom carbon (biomass) increases during bloom development, the dissolved iron-to-carbon (dFe:C) pseudo-uptake ratio decreases. Our study indicates that not only dissolved iron concentration but also the ratio of nitrate-to-dissolved-iron are important parameters that control diatom abundance, and hence high rates of primary production and an efficient carbon transfer through the Antarctic food webs.

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Diversity and ecological role of cyanobacterial benthic microbial mats in five lakes, Lützow-Holm Bay, East Antarctica

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Cyanobacteria in bottom benthic mats of five lakes in Lützow-Holm Bay, East Antarctica, were investigated by a multi-facet approach. Morphological (cell biovolume - three groups of cyanobacteria were determined according to their cell morphology: unicellular, filamentous, and heterocystous cyanobacteria) and molecular methods (NGS amplicon sequencing of cyanobacterial 16S rRNA) were combined with a characterization of their ecological role (nitrogenase activity). Five samples were collected from five lakes (Bosatsu-ike, Hotoke-ike, Nyorai-ike, Naga-ike, Skallen-ike), spanning a range of different ecological environments in the deglaciated areas of Skarvnes and Skallen. We evaluated the influence of lake characteristics on the cyanobacterial benthic mats' diversity and ecophysiological activity. In addition to cyanobacteria, eukaryotic microalgae (diatoms, coccoid, filamentous algae – Chlorophyta and Charophyta) were also distinguished. This research is supported by JARE-60 (Japanese Antarctic Research Expedition) 2018/19 and contributes to the long term monitoring of Antarctic lakes.

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How have Shackleton Glacier's soil fauna responded to deglaciation since the Last Glacial Maximum?

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Connections between the structure of soil communities and the role that geological legacies play in shaping them help us understand their response to environmental changes. The Transantarctic Mountains region experienced massive environmental changes associated with glacial recession since the Last Glacial Maximum (LGM), yet we have few clues as to how biotic communities responded. We recently surveyed the soil invertebrate fauna from above and below LGM elevations along two transects of the Shackleton Glacier (~9 features, two locations per feature) and investigated if habitat suitability, taxonomic diversity and community structure follow predictable patterns with distance from the LGM trim line. Our transects provide a gradient of surface ages that should reflect extinction and recolonization events across highly heterogeneous soil habitats. Our results indicate that soil fauna abundance and habitat suitability declined with increasing distance from the ice shelf (p abundance<0.001; p habitat<0.0001) and the nearest glacier (p abundance<0.01; p habitat<0.001). Soil fauna community structure was also affected by distance from both ice shelf (F=3.59, df=1, p=0.002, r2=0.40) and glacier (F=4.82, df=1, p=0.001, r2=0.53), with the omnivorous nematode genus Eudorylaimus relating to shorter distances from ice shelf (<10-20 km) and glacier (<200-400 m) if compared to rotifers, tardigrades, and other nematodes (Scottnema and Plectus), indicating higher trophic complexity in younger exposed soils. We conclude that distance from present ice surfaces (as a proxy for surface exposure time) is negatively related to habitat suitability, with decreases in soil fauna abundance and simplified community structure with increasing distance from present ice surfaces.

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Does size matter? Hydrology and habitat in “medium”-sized lakes and ponds, Antarctica

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The classification of Antarctic terrestrial lake and pond systems is based predominantly on size and morphology, as this influences the volume of liquid water, its chemistry and the habitat provided for aquatic life. However, the research underpinning this classification pertains mainly to small ponds, which freeze and thaw each year, and large perennially ice-covered lakes. There is currently little information on what might be termed “medium” sized-water bodies, and how the interactions of topography and temperature influence their evolution. In January 2019, medium-sized water bodies in a valley off the northwest margin of the Koettlitz Glacier, were investigated; Ward Lake (950m diameter), Burt Lake (735m) and Keyhole Lake (376 m). All were relatively shallow (<4m) with a predominantly frozen water column at the centre, but only Burt Lake was frozen solid, without liquid water or cyanobacterial mat development. Ward and Keyhole lakes had horizons of water-laden, candled ice within solid lake ice, moat and mat development and a thin layer of liquid brine at the very base of the lake ice. These observations indicated that the presence of active or intermittent inflow and outflow systems, and consequent changes in lake level over time, influence biological productivity to a greater degree than pond volume, surface area or depth.

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Pond ice gases as a record of ecosystem metabolic change during freezing

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Gases interred in Antarctic ice sheets have yielded critical information on long-term temporal changes in atmospheric gases. Gases trapped in the seasonal ice formed in Antarctic ponds and lakes, may likewise preserve a record of temporal changes in the metabolism of a pond's ecosystem during seasonal freezing; a record which is almost impossible to measure directly. Two 65cm ice cores collected from frozen ponds (JA & P70) at Bratina Island, on the McMurdo Ice Shelf, have been analysed using gas chromatography, after melting sections of ice core in a vacuum. Oxygen and nitrogen dominated the trapped gases at all depths in the core, with the proportion of oxygen dropping from 0.37 to <0.1 mole/mole of dry gas in the final stages of freezing (at the base of the ice core). In contrast, carbon dioxide increased with depth, from < 0.0004 in surface ice, to 0.35 mole/mole dry gas at the base of the JA core, and methane increased with depth only in P70, achieving a maximum of 3.5 mmole/mole dry gas. Other detectable trace gases; nitrous oxide, carbon monoxide, carbonyl sulphide, hydrocarbons, did not show consistent trends with ice core depth. When compared with temporal trends in water chemistry and primary productivity in these ponds, it is apparent that ice gas composition has faithfully reflected and recorded major shifts in metabolic processes during freezing.

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Adelie Penguin Habitat Requirements in relation to Geology and Geomorphology: Further developing the species-environment relationship

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The Adelie penguin is one of the most extensively studied avian species in the world. With this long history of research, the Adelie penguin has emerged as a key indicator species for climate change, assisting in identifying changes in the surrounding Antarctic landscape. With environmental conditions changing due to the growing pressures of climate change, it is important to understand the key drivers influencing Adelie penguin habitat requirements at a temporal and spatial scale. Although many aspects of Adelie habitat requirements have been extensively researched, there is still little known about their species-environment relationship in relation to geological and geomorphological requirements. Without this key information, predicting future habitat availability is challenging.
This project will primarily focus on Adelie populations distributed throughout the Windmill Islands. Using satellite imagery, aerial photos and ground-based data, significant geological and geomorphological aspects of the environment will be identified. This will be developed and contrasted against presence-absence data supplied from the Australian Antarctic Division. By compiling these data sets, potential patterns may be revealed that further our understanding of Adelie penguin habitat requirements and how this has changed with environmental conditions over time.

This project aims to further our knowledge on the key drivers that influence Adelie penguin habitat requirements. The results may assist in making projections of future habitat availability and predicting other possible impacts of climate change on Adelie penguin populations.

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The evolution of benthic invertebrate community ecology in the Cenozoic of Antarctica

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Assessing changes in the ecology of fossil communities, and how this affected the evolution of marine life, gives insight into how modern communities will react to environmental change. Modern Antarctic benthic invertebrate marine communities are described as archaic and retrograde, dominated by epifaunal suspension feeding organisms. Previous studies suggested this evolved in the Eocene, with cooling decreasing durophagous predation. However, some evidence does not corroborate this hypothesis. The Cretaceous-Paleogene mass extinction did not cause a distinct change in Antarctic benthic community ecology. However, other global signals, for example a shift in dominance between bivalves and gastropods, occur in the Paleocene. During the Eocene, there was a radiation of many taxa. Stalked crinoids, the main evidence for the original hypothesis that Antarctic community structure arising at this time, are present. However, we have linked this to asynchronous timing of the Marine Mesozoic Revolution in the Southern Hemisphere. Evidence of the first glaciations in the west Antarctica comes from King George Island (South Shetland Islands). The Polonez Cove and Cape Melville Formations preserve marine sedimentary sequences from the Oligocene and Miocene. Dropstones, diamictites and striated rocks confirm deposition in a glacial environment. Both preserve abundant fossils, representing Antarctica’s first glacial sea floor communities. However, the youngest unit, does not preserve an invertebrate community with the modern Antarctic ecological structure. It is dominated by infaunal bivalves, with a significant proportion of durophagous decapods. We hypothesise that the evolution of the modern benthic invertebrate community structure occurred more recently than previously thought.

1291

Past cyanobacterial biodiversity in polar regions

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Looking to the past, the FNRS project HERBA aims to study the past diversity and biogeography of cyanobacteria in polar regions by investigating herbaria specimens from the Smithsonian Institution (Washington, DC, USA). First results, obtained with 454 pyrosequencing of the 16S rRNA gene V3-V4 segment, showed that it was possible to retrieve the sequences of Antarctic samples taken in 1948-9 from Ross Island, in 1940 from Deception Island and in 1964 from Victoria Land. DNA could be amplified in all cases and 55 OTUs (97.5% similarity) were detected. Sequences of Nostoc sp., Microcoleus sp., Phormidesmis priestleyi, Leptolyngbya sp., and Timaviella sp. were retrieved and compared with present-day sequences. This study gives access to the cyanobacterial community composition in a period where anthropogenic and climatic pressures were still low in the remote polar regions and will allow to detect possible changes in biogeographic patterns or shifts of genotypes towards more generalist ones.

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MICROBIAN : Microbial diversity in the Sør Rondane Mountains in a context of climate change

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The Sør Rondane Mountains (SRM) represent a c. 900 km² large
mountain range, encompassing a large range of terrestrial habitats differing in geology and soil characteristics, exposure time and microclimatic conditions. The objectives of the BelSPO project MICROBIAN are to (i) use a combination of remote sensing (Digital Elevation Model) and close-range field observation techniques to map physical habitat characteristics and the presence/extent of biological crust communities in the region of the Princess Elisabeth Station Antarctica (PEA), (ii) generate a comprehensive inventory of the taxonomic and functional diversity of microbial communities in these habitats by amplicon sequencing of the 16S and 18S rRNA genes and metagenomics, (iii) use mesocosm field experiments (Open Top Chambers and snow fences) to mimic the possible effects of future climate change on the taxonomic diversity of these microbial ecosystems, and (iv) conduct field experiments to inform policy-makers in view of decision making regarding environmental protection and prevention measures to reduce the introduction and spread of non-native species and to avoid cross-contamination between sites. The proposed research will provide a proof of concept to use high resolution satellite images for identifying regions of particular biological interest in East Antarctica and more broadly make a significant contribution to understanding Antarctic terrestrial microbial ecology.

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Effect of environmental parameters on diversity, community composition, and functional guilds and growth forms distribution of fungi in Victoria Land soils

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Ice-free areas of Victoria Land are patchily distributed, mainly restricted to coastal regions, mountain peaks and to McMurdo Dry Valleys. Exposed soils concentrate most of the terrestrial biota and are important oases supporting unique edaphic communities, that more than in other continents, are made up of microorganisms, playing key roles in soil ecology and sustainability. Despite the well-known role of fungi in soil ecosystems in recycling C sources and their high resistance to desiccation and UV radiations, their role in Antarctic soils received little focus until now. Through ITS1 rDNA metabarcoding, we characterized the fungal communities of 65 soil samples from 9 different localities in coastal sites of Northern Victoria Land and inland sites of Southern Victoria Land. We obtained 896 OTUs, among which 495 were assigned to functional guilds, that were dominated by lichenized and saprotrophic fungi. When possible, we identified the growth form (filamentous, yeast or meristematic) for OTUs with high identity with known fungal genera and families. Diversity, community composition and distribution of different functional guilds and growth forms were related to the geographical distance of sampling sites and to different edaphic parameters (soil texture, pH, moisture, C, N, available P, cation exchange capacity and exchangeable cations Na^+, K^+, Mg^{2+} and Ca^{2+}), in order to: i) give insights into soil/fungi dynamics from costal to inland areas of Victoria Land in relation to the extreme environment to which they are adapted and ii) define the main drivers of their distribution.

SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 31

BIOLOGICAL DISPERSAL - CONNECTIONS AT CONTINENTAL AND INTER-CONTINENTAL SCALES

Ceridwen Fraser, Papetti Chiara
Henrik Christiansen, Valérie Dulière

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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A synthesis of genetic structure across the Antarctic

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The genetic structure of populations crucially reflects their capacity to adapt or disperse in response to ongoing environmental change. There is now a substantial body of work addressing the genetic diversity and connectivity of Antarctic taxa, yet no systematic, quantitative synthesis of this data to inform future research or conservation priorities. In response, we have developed a comprehensive database of intraspecific genetic research on Antarctic and sub-Antarctic flora and fauna. Preliminary review of these studies reveals numerous emerging patterns regarding the scope, focus and findings of Antarctic connectivity research, including clear biases in sampling effort. A meta-analysis of these studies will help identify the most genetically vulnerable Antarctic populations, based on taxa, biogeographic region, dispersal mode and habitat. The database will be made openly accessible to provide researchers context and comparison for any future work regarding the connectivity and genetic diversity of Antarctic biota.

1191

Midway upon the journey of life: the importance of local and regional hydrography on population connectivity in Antarctic fish

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As Dante observed, the fate of individuals rests upon the whims of their environment. In the diverse array of notothenioid species, that environment is characterized by the prevailing current systems to which they are exposed throughout their life history. Many Notothenioids filling pelagic as well as demersal niches have evolved energy-conserving life strategies to reserve resources in the polar environment. This, coupled with their protracted life histories that combine extended early pelagic stages of more than a year with lifespans that extend into the multi-decadal range, disposes Notothenioids to complex connectivity scenarios over their life history. The occupation of different water masses by different life stages, coupled with circulation related to bathymetric features like glacial troughs and sea mounts, can serve to close the life cycle, informing the distribution of fish throughout their life history and the structure of their populations. Nevertheless, on the circumpolar scale, the Antarctic Circumpolar Current and the anticlockwise Antarctic Slope Current represent transport pathways that promote zonal movement within and across regions. The Antarctic Coastal Current, fed by glacial run off and hugging the coastline, connects inshore habitats on a more local scale. Temporal variability in these otherwise consistent hydrographic features has been shown to impact connectivity over time on seasonal and interannual scales. This presentation will explore the latest evidence for the integral role of hydrography and its influence on advective loss and supply to habitats downstream, when, as Dante's protagonist found, "the straightforward pathway had been lost".

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Revisiting the bipolarity of Roaldia revoluta (Mitt.) P.E.A.S. Câmara & M. Carvalho-Silva (Bryophyta, Pylaisiaceae)

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Roaldia revoluta (Bryophyta, Pylaisiaceae) is a strict bipolar moss, with an arctic-boreal-montane range, and in the southern hemisphere it is present in Antarctica (South Orkney, South Shetlands and Peninsula), Patagonia and New Zealand. Three main theories have arisen to explain the bipolarity: (1) American pathway with dispersal to the neotropics via mountain ranges to maritime Antarctica via Patagonia, (2) African pathway by means of east Africa mountains to sub Antarctic islands such as Kerguelen and (3) Indomalayan-Malesian Pathway, from Southeast Asia to Southeast Australia, New Zealand and associated islands. In this study we used a molecular approach to investigate the genetic evolution and relationships among representatives of R. revoluta from different parts of the globe. Nuclear (ITS + 26S) and Chloroplast marker (rpl16) were selected; total DNA was extracted from fresh and herbaria material. The results of our molecular analyses have shown very low genetic diversity among populations of R. revoluta across the globe. Both DNA regions has shown the existence of four haplotypes; the specimens from Antarctica all belong into Haplotype 1, the most widespread one. Although it was not possible to trace the species' precise dispersal route, we can assume that the American pathway hypothesis would be more appropriate since the populations with the highest number of haplotypes (for both types of markers) appear to follow the Europe – North America – Antarctica route.

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Spatial population genetic patterns and seed dispersal syndromes in plants on sub-Antarctic Marion Island

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Seed dispersal in plants comes in many forms, including by gravity, wind, water, ingestion by animals, and attachment to animals, and is expected to influence population genetic and biogeographic patterns. Sub-Antarctic islands represent ideal model systems for the study of evolutionary and ecological processes because of their simple and bounded yet well-developed terrestrial ecosystems and the presence of a diversity of biological and physical features in different species and different islands. Sub-Antarctic islands also feature unique environments with distinct species assemblages that are expected to be highly impacted by rapid environmental change, including climate change and the spread of alien invasive species. Understanding ecological and evolutionary processes, like dispersal and gene flow, can help predict species' responses to such changes. In this study, we focus on two plant species on sub-Antarctic Marion Island in the South Indian Ocean, the gravity-dispersed Azorella selago (Apiaceae) and epizoochoric Acaena magellanica (Rosaceae). We collected genome-level SNP data using Restriction site-Associated DNA Sequencing from populations across Marion Island, and compare spatial patterns in genetic diversity, genetic structure, and gene flow. We found a strong geographic gradient in genetic diversity in Azorella selago corresponding with the prevailing wind direction and the hypothesised location of a glacial refugium. In Acaena magellanica, we found no clear spatial patterns in genetic attributes, which may be indicative of greater dispersal distances and greater genetic connectivity across the island in this animal-dispersed species.

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Large scale connectivity of the marbled rockcod Notothenia rossii revealed through population genomics and modelling

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Ecological and evolutionary connectivity between population patches has important implications with respect to species distribution, population viability and local adaptation. The marbled rockcod Notothenia rossii was historically overharvested in the Southern Ocean and only recently shows signs of recovery. The species' distribution is fragmented between continental shelf, oceanic island plateaus and seamount regions. We applied a combination of species distribution modelling, individual-based dispersal modelling and population genomics to investigate genetic structure and connectivity of this ecologically important species. High resolution genomic data reveals apparent panmixia with virtually no genetic differentiation over vast distances. Individual-based modelling, however, indicates that large scale connectivity can only be achieved via stepping-stone transport. Species distribution models furthermore suggest that N. rossii may rely on previously unrecognized stepping-stone habitats for example at Bouvet Island and the Ob and Lena banks. We speculate that these results can partly explain the long recovery time of this species. Current conservation plans in the Southern Ocean can benefit from such multi-method assessments, especially in view of global change.

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Bacterial hitchhikers tell tales of Antarctic krill dispersal

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Antarctic krill (Euphausia superba) are amongst the most abundant animals on Earth, with a circumpolar distribution in the Southern Ocean. Krill are also the focus of an expanding fishery that is managed using regional catch limits, but it is unclear whether there is a single krill stock throughout these regions or if demographically distinct populations inhabit some regions. We show that Antarctic krill-associated bacterial communities exhibit spatial structuring, with some differentiation even at scales of a few kilometres. Linear mixed effects modelling showed this differentiation is almost entirely driven by spatial rather than environmental factors, especially for strongly krill-associated bacteria. Estimating the ecological processes driving bacterial community turnover showed this was driven by increasing dispersal limitation (rather than natural selection) with increasing geographic distance. Furthermore, divergent bacterial communities were generated from a single krill swarm split between aquarium tanks under near identical conditions, suggesting that physical isolation rather than environmental factors can cause krill-associated bacterial communities to diverge. Our results suggest bacterial hitchhikers provide unique insights into krill population subdivision and illustrate the broad potential for host-associated bacteria to inform studies of animal population structure.

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Opportunistic fungal assemblages present on fairy rings spread on different moss species in Antarctic Peninsula

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In recent years reports have been reported in several places of Antarctica, about mosses seem to be attacked by an uncertain organism. In these phenomena, the formation of a concentric ring characterizes the attack that ultimate result is the moss death. Moss samples with fairy rings were obtained in different sites across the South Shetlands. Only the sick part of the mosses was collected and stored in sterile plastic bags at 10 °C until the processing at the Laboratory of Polar Microbiology and Tropical Connections, Brazil. Small pieces of the mosses were inoculated on the Potato Dextrose Agar supplemented with 200 µg mL^{-1} of chloramphenicol and incubated at 10 °C for 60 days. All sampled mosses were identified according to its macro- and micromorphological characteristics and using keys and literature. From the different mosses species with fairy rings, we isolated 40 fungal taxa. We provide an update on the host species identification with novel mosses with fairy ring effect. Sanionia uncinata shelter the highest fungal richness. Mortierella detected in all the mosses surveyed and represented the fungi most abundant recovered. However, others taxa present in the fairy ring mosses were already reported as opportunistic plant pathogens agents such as Cladosporium sp. and Phoma herbarum. We hypothesized that the some fungi recovered from fairy rings mosses might represent opportunistic secondary pathogens occurring after the first attack of known fungus Psychronectria hyperantarctica and, contributing to decreasing of natural defense of the sick mosses and accelerating its dissemination in Antarctica Peninsula.

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Evolutionary history of Halicarcinus planatus, first marine alien reaching Antarctica

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In 2010, a breeding female Halicarcinus planatus (Decapoda, Brachyura) was collected in Deception Island (South Shetlands), nevertheless its native distribution is circum-Subantarctic. Halicarcinus planatus has a low bathymetric range, a planktonic larval duration of 45-60 days, and may tolerates negative temperature because it is able to down-regulate the Magnesium concentration in the haemolymph that increases with the cold.

The appraisal of its presence along the West Antarctic Peninsula indicates that Halicarcinus planatus no longer occurs in Antarctica. The phylogenetic relationships among mitochondrial and nuclear haplotypes of Halicarcinus spp. display a basal position of H. planatus related to its congenerics, as well as a clear separation between H. planatus samples from Auckland-Campbell Islands and the remaining group from Pacific coast of southern South-America, Falkland/Malvinas, Kerguelen. The levels of mitochondrial diversity of Halicarcinus planatus populations are the highest known so far in southern South America, but tend to decrease toward the north, whereas in Subantarctic islands they are significantly lower. The mitochondrial haplotype network is dense and strongly reticulated, showing sign of population-size reduction only in Kerguelen. Eight microsatellites loci helped to reveal a significant genetic differentiation among all samples, except among those from Kerguelen. Cluster analyses separates Kerguelen samples from the rest. Despite the long duration of the planktonic phase, it seems that the dispersal capacity of Halicarcinus planatus does not allow to homogenize populations across the Southern Ocean. The more recent but very limited gene flow that existed between Patagonia and Kerguelen would have more likely occurred by rafting.

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Hidden diversity in the periwinkle Laevilitorina caliginosa across its distribution in the Southern Ocean.

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The origin of the Antarctic Circumpolar Current (ACC) around 30 Ma shaped past and present oceanographic patterns in the Southern Ocean (SO) and this oceanographic feature is also considered as a main biogeographic driver. Accordingly, a main paradigm of the SO biogeography is the high levels of endemism and the marked bioregionalization between the Antarctic and the sub-Antarctic biota. Nevertheless, there are several examples of broadly distributed SO organisms that challenge this view, including the periwinkle Laevilitorina caliginosa distributed across Antarctic and sub-Antarctic provinces. Here we performed an integrative biogeographic study in L. caliginosa across its distribution in the SO. Through multi-locus phylogenetic analyses and divergence time estimates we analyzed evolutionary patterns in the species. Phylogenetic reconstructions based on mtDNA and nucDNA markers and morphological comparisons recorded the presence of seven evolutionary units within the nominal species L. caliginosa. Among them, a single lineage was effectively found in the Antarctic Peninsula but it expands its distribution towards geographically distant sub-Antarctic areas like Marion, Crozet and the Kerguelen islands. The rest of the lineages (six) are endemic to the Magellan province, three of them in the Strait of Magellan, two in Cape Horn and a single one in the Malvinas/Falklands islands. Divergence time estimates suggest that the origin and diversification of Laevilitorina occurred long after the physical separation of the provinces where they are currently found. Moreover, molecular and morphological results suggest that the Magellan province represents an area of diversification for Laevilitorina, as recorded in other SO marine mollusks.

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Contrasting biogeographical patterns in the vetigastropod genus Margarella across the Antarctic Polar Front.

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This study aims to understand phylogenetic relationships and diversification rates in the genus Margarella from South America, the Antarctic Peninsula, and sub-Antarctic islands. Through multi-locus phylogenies and time-calibrated analyses we resolved biogeographic signals in the group. Out of seven nominal species analyzed, species delimitation analyses recognized only four significant evolutionary units. Margarella antarctica occurs exclusively across the Antarctic Peninsula while two lineages were found in South Georgia (M. achiles and M. steineni). A fourth lineage included sub-Antarctic Margarella populations belonging to M. expansa, M. porcellana, M. pruinosa, and M. violacea collected between South America and the Kerguelen Islands. In spite of the clear morphological variation recorded in these sub-Antarctic specimens, they should be considered as M. violacea, following taxonomic description criteria. Mitochondrial divergence-time estimates suggest that the origin and diversification of these four evolutionary units occurred at the end of the Miocene, between 7 and 5 Ma. We recorded also contrasting biogeographical patterns in Margarella where the sub-Antarctic species, north of the Antarctic Polar Front (APF), is distributed across thousands of kilometers while Margarella species distributed south of the APF showed a much narrower geographical distribution and high levels of endemism. Such contrasting patterns may be the consequence of the presence/absence of buoyant kelps across the APF, which are potential long-distance vehicles for these vetigastropods. Accordingly, north of the APF, Margarella would maintain connectivity through rafting while inside this boundary the absence of buoyant kelps may preclude the admixture of lineages between the Antarctic Peninsula and South Georgia.

37

Passengers into the cold: Invasive marine species discovered on non–native kelp rafts in the warmest Antarctic island

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Antarctic shallow coastal marine communities were long thought to be isolated by hundreds of kilometres of deep ocean and the Antarctic Circumpolar Current. The discovery of non–native kelp washed up on Antarctic beaches led us to question the permeability of these barriers. Over 70 million kelp rafts are afloat in the Southern Ocean at any one time. These living, floating islands can play host to a range of passenger species including from their original coastal location and those collected en route. Driven by winds, currents and storms towards Antarctica, these rafts are often cited as theoretical vectors for the introduction of new species into continent and the sub-Antarctic islands. We found non-native kelp, with a range of "hitch-hiking" organisms, on an Antarctic beach inside the flooded caldera of an active volcanic island. This is the first evidence of non-native species reaching the Antarctic continent alive on kelp rafts. One passenger species, the bryozoan Membranipora membranacea, is an invasive and ecologically harmful species in some cold-water regions, and this is its first record from Antarctica. The caldera of Deception Island provides considerably milder conditions than the surrounding waters and it could be an ideal location for newly introduced species to become established. These findings help to explain many of the biogeographic patterns and connections we currently see across the Southern Ocean. However, with the impacts of climate change we may see an increase in the number of species capable of surviving the long journey and becoming successfully established in Antarctic waters.

1109

Monitoring change in East Antarctic vegetation communities over a decade using digital photography

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Climate change is affecting Antarctica and minimally destructive long-term monitoring of its unique ecosystems is vital to detect biodiversity trends, and to understand how change is affecting these communities.

We assessed moss health and species composition at seven time points between 2000 and 2014 at two East Antarctic sites. Semi-automatic object-based image analysis (OBIA) was used to classify digital photographs using a set of rules based on digital red, green, blue (RGB) and hue-saturation-intensity (HSI) value thresholds, assigning vegetation to categories of healthy, stressed or moribund moss and lichens. Microsamples of moss were identified to species level for analysis of species composition.

Overall moss health, as assessed using the mean percentages of healthy, stressed and moribund mosses within quadrats, changed over the period of study at both sites, as did species composition. A marked increase in stress and decline in health was observed across both sites in 2008, followed by recovery to baseline levels of health by 2014 at one site, but with significantly more stressed or moribund moss remaining at the other site. This was associated with a decrease in Schistidium antarctici and an increase in Ceratodon purpureus at both sites.

These results have informed a conceptual framework for monitoring the changing condition of Antarctic mosses. These communities are potentially important proxies for monitoring coastal climate change in Antarctica and further ongoing monitoring is required to ensure their appropriate management and protection.

1190

Biogeographic patterns in the mesopelagic realm from the Arctic to Antarctic: a case study of two panoceanic chaetognaths and one euphausiid with antitropical distribution

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Mesopelagic species with panoceanic distribution are traditionally considered as single-species taxa. However, recent molecular studies provided evidences for a presence of several cryptic or pseudocryptic species within each of these taxa. The cryptic speciation can heavily bias our perceptions of large-scale biogeographic patterns that calls for a retrieval of the true diversity within common and ecologically important groups. We present a case phylogeographic study of two mesopelagic chaetognaths (Eukrohnia hamata and Pseudosagitta maxima) and one euphausiid (Nematoscelis megalops), which show similar biogeographic patterns in distribution. Both chaetognath species are widespread, ranging from the Arctic to the Antarctic zone of the Southern Ocean and dominating in the Polar and Subpolar regions. The euphausiid N. megalops occurs in warm-temperate belts of the North and South Atlantic, Indian Ocean and South Pacific. We analyzed the molecular (mtCOI, H3 and additional ITS1 for P. maxima, 28S and 18S for E. hamata) diversity of these species throughout the Atlantic Ocean from 65° S to 85° N. Phylogenetic analyses retrieved several distinct mitochondrial clades within these species, most of which are geographically separated: two clades of N. megalops, three clades of P. maxima, and five clades of E. hamata. All three species encompass different clades in the Northern and the Southern Hemispheres, two clades of E. hamata are divided by the South Polar Front. In some cases genetic differences between clades are supported by morphology and/or size structure (the latter is for E. hamata population in the Southern Ocean).

1663

Assessment of the capacity of Halicarcinus planatus to arrive and settle as a potential invasor of Antarctic shallow ecosystems.

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Halicarcinus planatus is a small brachyuran crab distributed in shallow marine waters of southern South America and Sub-Antarctic islands. This species has a planktonic larval duration of 45-60 days and is also able to down-regulate the Magnesium concentration in the hemolymph that tends to increase with colder conditions. Due to this physiological characteristic, associated to the high dispersal potential, H. planatus has been historically considered as a potential invader of Antarctic shallow ecosystems. In 2010, a single ovigerous female of H. planatus was found in Deception Island. The aim of this study is to evaluate the invasive potential of H. planatus to settle in Antarctica. The results of lagrangian model of particle diffusion simulation showed that Patagonian larvae cannot reach the Antarctic Peninsula due to the Antarctic Circumpolar Current that forms a strong barrier. The assessment of genetic structure and connectivity through SNPs analyses among South Patagonia and Sub-Antarctic Islands identified 3 main groups: New Zealand, Kerguelen and South America. Overall, the dispersal capacity is low, but may reach a distance 1000km. Nevertheless, a single individual in Kerguelen was assigned to Patagonia, 8000 km away. The survival assessment in Antarctic conditions indicated that the crab died after 15 days at -1°C. Consequently, niche model show that the species cannot live in Antarctica before 2100 (RCP8.5). To conclude, in the present day, Halicarcunus planatus is neither able to reach Antarctica by dispersal way, nor to settle in Antarctic shallow ecosystems, yet. However, it will be a potential invader in 80 years.

350

Contrasting dispersal patterns in Antarctic Cassidulinidae, benthic foraminifera

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Cassidulinidae, although distributed worldwide, are one of the most characteristic rotaliid benthic foraminifera inhabiting the Antarctic continental shelf. This study focuses on two genera, i.e. Cassidulinoides and Globocassidulina, that show strikingly different geographical ranges and genetic population structures, that are based on ~1000 bp fragment of the SSU rDNA. While different species of Antarctic Cassidulinoides show limited ranges and very simple, star-like shaped haplotype networks, two species of the genus Globocassidulina show wide, possibly circum-Antarctic distributions and complex haplotype network structures. For the representatives of the first genus, limited dispersal following a population bottle neck is suggested, while representatives of the second seemed to survive the last glaciation retaining genetically diverse populations either in multiple refugia or in deep-sea settings. This pronounced difference is probably due to varying dispersal potential of propagules, that are probably more persistent in the case of Globocassidulina. The Bayesian phylogenetic reconstruction suggests that the diversification of Antarctic Cassidulinidae occurred after their separation from sub-Antarctic lineages following the Middle Miocene, which was one of the main stages of progressive thermal isolation of the Antarctic.

424

Assessing connectivity among moss populations in Antarctica and the Southern Hemisphere using targeted exon capture

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Antarctica has long been considered a biologically isolated continent, with this driving evolution of the region's unique biota. Though we know that many species have survived for millions of years on the continent, weathering Pleistocene (and earlier) glacial periods, we still know little about where glacial refugia were located. In addition, a range of new studies are suggesting that colonisation of Antarctica by terrestrial species has occurred over more recent timescales through natural incursions, but we lack knowledge of the extent of genetic connectivity for taxa within and beyond the Antarctic. With global environmental change leading to significant warming and increased habitability of parts of Antarctica, there is an urgent need to assess the extent to which Antarctica truly is biologically isolated. Fundamental to this is determination of the processes that drive evolution and structure spatial patterns of biodiversity, and a better understanding of the likelihood, mechanisms and consequences of future dispersal events, both natural and anthropogenic. Here, we apply genomic methodologies (targeted exon capture) to three widespread moss species collected from across the continent, throughout the sub-Antarctic, and from surrounding Southern Hemisphere landmasses. We use these data to infer refugial locations, assess dispersal and diversity patterns, and determine the source regions for past and recent moss colonisations of Antarctica. We hypothesise that some populations in Antarctica will show low diversity and close genetic affinities with other landmasses, reflecting recent arrival in Antarctica.

1692

Molecular divergence in Adenocystis utricularis (Bory) Skottsberg 1907 co-distributed through the Magallanes Region, Subantarctic island and the Antarctic Peninsula

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The distribution of the biota of the Southern Ocean is the result of great geological, oceanographic and climatic changes during the last 50 million years (Ma). However, several groups of benthic marine organisms exhibit marked taxonomic similarities between the Antarctic Peninsula and the southern coast of South America where families, genera, and even species are currently co-distributed in these continents. Macroalgae, such as Gigartina skottsbergii and Iridaea cordata, are located on both sides of the Drake Pass. Advances in molecular techniques have allowed us to determine phylogenetic relationships and levels of molecular divergence between populations of both continents to estimate whether they constitute separate evolutionary units. In this study it was determined through the use of molecular markers, COI5P and rbcL if the nominal species Adenocystis utricularis represents the same evolutionary unit in Antarctic and sub-Antarctic populations. According to the results, Adenocystis showed the presence of five different evolutionary units between the Antarctic Peninsula, the Sub-Antarctic Islands and the Magellan region, for both markers. Interestingly, a high affinity was found between haplotypes of subantartic islands such as Kerguelen and Yerbas Buenas with Antarctic Peninsula. Such results are similar to those recorded among populations of G. skottsbergii on both sides of the Drake Pass. In this way, Adenocystis populations on both sides of the Drake Passage, is presented as a cryptic species. In this context, cryptic speciation plays an important role in the evolution of the Southern Ocean and therefore, the systematic, biogeography and biodiversity of the region require major revisions.

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Future challenges for notothenioid population genetics and connectivity studies

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Insights gained from genetic studies of Antarctic notothenioids over the past 25 years within the context of the Southern Ocean system emphasize the complex ways, at different life stages and along multiple pathways, in which habitat, ocean circulation and life history can interact to structure populations and their connectivity. These studies also suggest how multidisciplinary approaches incorporating hydrography can inform understanding of genetic structuring and gene flow around the Antarctic. From this background, this contribution will begin synthesizing biophysical hypotheses that can help explain gene flow in a range of species. The identification of gaps of knowledge and related open questions will help to guide future multi-disciplinary and disciplinary-specific tests. Given the current documented threats to the Antarctic biodiversity, it appears timely to adopt a wider view on population connectivity in Antarctic notothenioid fish, to develop a systemic perspective and integrated approaches capable of addressing the new challenges for future genetic investigations. Such integrated studies are relevant not only to enhance our understanding of the ecology and evolutionary trajectories of Antarctic fish, but also to support important conservation measures. Ultimately, decisions governing the choice of size, number, spacing and location of protected areas should reflect species-specific patterns of population connectivity and dispersal, gene flow and genetic structuring.

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Species, hybrids and populations of Chionodraco spp. icefishes in Weddell Sea

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Once considered an occasional event across animal species, hybridization is now seen as a widespread phenomenon. Hybridization can promote genetic diversity and help the rescue of inbred populations, but it can also decrease the reproductive success of individuals by the production of unfit hybrid offspring and lead to genetic homogenization disrupting local adaptations. Here, we analyse the extent of hybridization among three species of icefish belonging to the genus Chionodraco (order Perciformes, suborder Notothenioidei, family Channichthyidae). Notothenioid are extensively studied in evolutionary biology since they represent an important example of adaptive radiation, one of the most relevant in the marine realm. By means of a panel of 18 microsatellite loci, we investigated the species boundaries, population genetics and phylogeographic patterns of the species Chionodraco hamatus, Chionodraco myersi and Chionodraco rastrospinosus. These species are morphologically very similar and difficult to distinguish. C. hamatus and C. myersi are sympatric while C. rastrospinosus is allopatric compared to the other two species. We discovered that C. rastrospinosus has a larger distribution than previously known, coming in contact with the two other species in Weddell Sea and hybridizing with them. In order to understand the possible routes of dispersion, a Lagrangian particle model of the regional oceanic currents was also implemented. Understanding the population dynamics of species, especially the factors modulating demography and gene flow among populations, is crucial for future predictions of species evolutionary trajectories and for a clear description of biodiversity.

1217

Pathogenic potential of thermophilic isolate Aspergillus fumigatus isolated from ornithogenic soil of Antarctica

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Aspergillus fumigatus is the most commonly involved in cases of aspergillosis in immunocompromised patients. We recovered a strain of A. fumigatus from ornithogenic soil of Antarctica, which displayed potential in vitro virulence such as the capability to grow at 37° C, different pH, produce spores ≤1 µm, and resistance against antifungal drugs. Due the increase incidence of aspergillosis caused by A. fumigatus in immunocompromised patients, we performed in vivo assays inoculating different concentrations of A. fumigatus spores in healthy Balb C mice. When fungal spores were inoculated at 1 x 108 spores⁄mL in immunocompromised Balb C mice, fungus was lethal. Our results indicated the fungi as A. fumigatus living in Antarctica should be monitored and studied to avoid health risks of dispersion to out of Antarctica.

1216

In vitro virulence of Antarctic Pseudogymnoascus fungi of Antarctica

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Pseudogymnoascus destructans is reported in different substrates of Antarctica and considered a psychrophilic pathogenic species and responsible for the reduction of the bat population in North America and Eurasia through the White Nose Syndrome (WNS). Despite the importance, there is no information on the virulent potential in vitro of Pseudogymnoascus in Antarctica. Eleven isolates of the genus Pseudogymnoascus obtained from different substrates of Antarctica were selected to assess its pathogenic potential in the present study. Six isolates were able to grow at temperatures of 5 to 28 ºC, pH ranges 4, 7, and 9, and showed phospholipid, esterase, and hemolytic activities. Their spore sizes ranged from 2.1 µm ± x 0.5 µm ± to 3.4 µm ± x 0.5 ± µm, indicating the potential for penetration into the pulmonary alveoli. Four isolates were resistant to fluconazole. The MIC values ranged from 0.25 to 0.5 µg in assays performed with itraconazole and 0.5 µg with amphotericin B. The results obtained in vitro indicate that virulence factors presented by Pseudogymnoascus isolates of Antarctica are relevance, raising concern regarding its possible spreading in the face of global warming.

1221

Global warming and the emergence of pathogens trapped in Antarctic permafrost

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In the present study, we aimed to identify and characterize virulence potential fungi present in the Antarctic permafrost the King George and Deception islands. Permafrost samples were processed in different culture media and incubated at 37 °C for 60 days. After the selective temperature growth, different isolates of Aspergillus hiratsukae, Aspergillus thermomutatus, and Rhodotorula mucilaginosa were obtained. These isolates were assayed about their growth resistance at temperatures up to 50 ºC, growth in different pH ranges, hemolytic activities, and the production of hydrolytic enzymes. Aspergillus isolates were able to grow at 45 ºC and R. mucilaginosa at 50 ºC. All isolates were able to grow in all tested pH ranges, produce proteinase enzymes and create a halo of hemolysis in blood agar. All taxa tested here are already reported as human pathogens in immunocompromise patients. The in vitro results indicated that these permafrost Antarctic fungi display virulence factors and may represent a concern as to their possible dispersion in the face of global warming.

1633

Taxonomic Studies of the Syntrichia Brid. in Antarctica

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Antarctica has a unique biodiversity, adapted to extreme conditions such as intense cold, high ultraviolet radiation and low humidity. In this continent, mosses are the predominant vegetation. Among the most diverse moss families in Antarctica is Pottiaceae, with 10 described genera, the most diverse being Syntrichia Brid. with five species (Syntrichia caninervis Mitt., S. filaris (Müll. Hal.) R.H. Zander, S. magellanica (Mont.) R.H. Zander, S. sarconeurum (Hook. F. & Wilson) Ochyra & RH Zander and S. saxicola (Cardot) R.H. Zander). It is a taxonomically complex group, due to its morphological variability and close proximity to other genera of the family like, leaving a gap on the understanding of relationships between taxa, especially due to the scarcity studies involving DNA. Seeking a better knowledge of the Antarctic species of Syntrichia and their relationships within the genus, a phylogenetic study was carried out using nuclear DNA sequences (ITS2 region). DNA was obtained from collections made in different parts of Antarctica and Subantarctica, as well as from herbarium specimens. Between one to five DNA sequences were obtained for each target species and analyzed under Maximum Parsimony, Maximum Likelihood and Bayesian Inference. Our results show that three of these species correspond to Syntrichia filaris, S. magellanica, and S. saxicola. Syntrichia sarconeurum has a different distribution than presented in the literature, excluding the samples cited for Princess Elizabeth Land, which correspond to an unknown group. As for Syntrichia caninervis, the studied samples correspond with another species, also belonging to the genus. All species exhibited monophyletism.

1228

Ecological processes influencing the bacterial and microbial eukaryote assemblages within the Southern Kerguelen Axis region

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Biologically productive Southern Ocean (SO) waters are an important site for nutrient recirculation, support primary production of global oceans, and drive significant carbon dioxide sequestration via physicochemical processes and the biological pump. Biological pump processes are microbially driven with substantial contributions from bacteria and microbial eukaryotes, and the biological pump's efficiency is highly dependent on the microbial community present. Ecological processes generating commonly observed biogeographic patterns (selection, dispersal, drift and speciation) are central to understanding microbial biogeography but remains poorly investigated in the SO. Based on 16S and 18S rRNA sequences generated from 36 surface samples within the Kerguelen Axis region, we quantified the ecological processes and spatial, environmental and biological interactions shaping bacterial and eukaryote communities. Our null-modelling approach results inferred that selection was a much more important determinant of bacterial community composition variations, whereas dispersal limitation, at the same scale, was 2 to 9-fold more important for eukaryote communities compared to bacteria. Besides environmental conditions, seasonal variation and spatial distance, biological interactions amongst microbes may also structure microbial communities. Spatial and commonly measured environmental factors explained 50% or less of variation among bacterial and eukaryote communities, suggesting potentially important roles of biotic interactions. Among the significant biotic interactions detected, 27% were inter-domain bacterial-eukaryote interactions extensively involving copiotrophic Flavobacteriales and parasitic Syndiniales that were over-represented compared to their relative abundance. Validating these microbial interactions and quantifying their relative importance in structuring SO microbial communities compared to abiotic factors, will help understand the response of SO ecosystems to environmental change.

1081

The COPE project: Conservation management of polar ecosystems using genomic approaches to study connectivity across spatial and functional scales

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Recently the second of several planned large Marine Protected Areas (MPA) has been set up in the Southern Ocean. MPAs are most effective if implemented as a network that considers functional diversity within and between species, relying on scale-dependent connections between MPAs. Three key features of connectivity are important in this context: 1) geographic or landscape connectivity, 2) environmental or habitat connectivity, and 3) genetic connectivity. While knowledge on geographic bio-regionalisation is fairly well-advanced, in-depth estimates of environmental and genetic connectivity require further development. In the COPE project, ecological niche models and population genomic approaches complement each other to advance the understanding of spatial connectivity in key benthic and pelagic Antarctic organisms (crustaceans and actinopterygian fishes). Connectivity is investigated at ecological (contemporary) and evolutionary (heritable/adaptive) scales. Thousands of genomic variants, obtained by reduced representation sequencing or shallow whole genome re-sequencing, will provide estimates of neutral and adaptive genetic variation at several trophic levels. In COPE, these estimates are used to characterize the ecological and evolutionary components of connectivity across space. The genomic information will be integrated in ecological niche modelling at the habitat and population level. COPE's results are expected to considerably advance our understanding of the spatial and functional distribution of biological variation in the SO. These insights will contribute to the Marine Ecosystem Assessment of the SO (MEASO) and will be directly applied at the political level to develop suitable management and conservation strategies through the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

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Otolith chemistry provides powerful natural markers to test hypotheses concerning bio-physical interactions in the Southern Ocean: with some case studies as examples

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In the natural world no organism exists in isolation, and every organism must interact with the environment and other organisms. Such interactions are fundamental to survival and biological processes at the population and ecosystem levels. The inherent complexity of the marine environment often requires the overlap of disciplines which are more traditionally separated. The manner by which various marine life forms are influenced by their surrounding physical environment represents an interface between biology and physics that is an often overlooked area of research, but one which can be rich in cross-disciplinary information incorporating currents, frontal dynamics, and eddy activity. Biochemical approaches are used widely to examine the life history processes of marine animals, and chemistry deposited in fish otoliths offers several biochemical markers to understand bio-physical interactions in marine fish species. In this talk, we will focus on investigating coupled biophysical processes in the Antarctic fish Electrona antarctica, Electrona carlsbergi, Pagothenia borchgrevinki and Dissostichus mawsoni, which occupy different habitats in the Southern Ocean. In particular, results from E. antarctica suggest the potential for otolith chemistry as a powerful natural tag to help understand the bio-physical interactions shaping population structure and dispersal across different habitats in the Southern Ocean.

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SESSION 32

GENOMIC INSIGHTS INTO PAST AND PRESENT ANTARCTIC BIODIVERSITY

Elie Poulin
Peter Convey, Claudia Soledad Maturana Bobadilla

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Biodiversity in Antarctic shallow benthic hard-bottom communities: metabarcoding as a tool for biodiversity assessment

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Marine benthic communities living in three-dimensional structures built mostly by sessile suspension feeders, the so-called "animal forests", are among the most diverse ecosystems in the Biosphere and play a crucial role for planetary ecosystem services. Documenting the diversity of marine life is challenging because many species are cryptic, small, and/or rare, and belong to poorly known groups. Exhaustive and consistent qualitative or quantitative biodiversity assessments are particular challenging in complex hard substrates of Antarctica. Biodiversity assessment methods have recently been revolutionized by the application of metabarcoding techniques. In the present study, we used metabarcoding to characterize the complex communities inhabiting marine hard substrates in Antarctica for obtaining baseline inventories for future monitoring and management. Samples were taken by scuba diving along the West Antarctic Peninsula and the South Shetland Islands. All rocky-bottom communities (three replicates each) were sampled by carefully scraping a 25 × 25 cm quadrat and the samples were separated into three size fractions (mega, macro, and meiobenthos). A total of 99 samples were metabarcoded with the COI marker. The number of total MOTUs detected from all samples by Bayesian clustering was about 3000 from which around 2000 (66%) could be taxonomically assigned to the level of phylum or lower. The undetectability of some minor groups in this study is possibly related to the incompleteness of reference databases for Antarctic organisms. The application of metabarcoding techniques to characterize marine hard bottom communities will contribute to a reproducible eukaryotic biodiversity assessment of structurally complex communities.

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Reconstructing past Antarctic ecosystems using ancient DNA

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The study of ancient DNA from sediments (sedaDNA) is a new tool to characterise past marine ecosystems from deep ocean sediments, and has great potential for paleoclimate research. Recent improvements in ship-board sediment coring procedures have allowed far greater levels of contamination control and, along with refinements in sedaDNA sample processing, sequencing and bioinformatic techniques, now make the application of ancient DNA techniques to marine sediments eminently realistic. Our previous research has shown that sedaDNA from marine eukaryotes (including phytoplankton and higher organisms) is invariably low (~1.5% of metagenomic shotgun data when using the taxonomically informative marker gene 'small subunit ribosomal RNA' as reference). Therefore, we developed an optimised protocol for the extraction of ancient eukaryote DNA from marine sediments, achieving a broad eukaryotic biodiversity signal while retaining highly-damaged small DNA fragments, which are characteristic of ancient DNA. Using our new technique and further optimised bioinformatic pipelines, we were able to extract and analyse sedaDNA from deep ocean sediment cores collected off East and West Antarctica (Totten Glacier/IN2017_V01, Iceberg Alley/IODP Exp. 382). Our preliminary genetic community data revealed the presence of major groups of phytoplankton (e.g., diatoms, dinoflagellates) and microzooplankton (e.g., ciliates, foraminifera), as well as higher organisms such as crustaceans, molluscs and cnidarians, which are not normally part of the fossil record. These results demonstrate the breadth of biodiversity estimates possible through the application of novel sedaDNA techniques to Antarctic marine sediments, enabling the reconstruction of marine ecosystems across the food-web and through time in this climatically important region.

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Out of Africa and across the sub-Antarctic: an enigmatic beetle radiation unveiled

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The origin and evolution of Southern Ocean Island faunas have vexed naturalists for centuries. In an unprecedented genomic effort for the region's fauna, we have unravelled the evolutionary history of one of the most enigmatic species radiations across these islands: that of the endemic, flightless Ectemnorhinini weevils. Analysis of 515 genes from more than 80 weevil species globally reveals that the closest relatives of the Ectemnorhinini are African, providing support for early ideas about Southern Indian Ocean island affinities. Molecular dating provides a crown age for the group in the Eocene (approx. 40 Ma), in keeping with some of the oldest known subaerial portions of the Kerguelen islands. Evolution has thus been sustained in situ throughout island uplift, submergence, volcanism and glaciation, although a high rate of extinction is also evident from the phylogeny. Molecular biogeographic analysis reveals the Crozet islands to be a central source of diversity for the group, again in line with previous theories and suggestive of significant within-archipelago speciation. Despite their flightlessness, the weevils have dispersed extensively throughout their evolutionary history; not only from Africa but also repeatedly between islands and often against the prevailing West Wind Drift. Thus, we consider birds a likely mode of transport for these species. Whereas most weevils globally have radiated in parallel with flowering plants, this unique tribe diversified as the climate cooled and bryophyte-dominated fellfield habitat came to dominate the sub-Antarctic.

1505

Antarctic Biocrusts: Unravelling their composition and functionality in the cold drylands

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Antarctica is characterized by having some of the most severe climatic conditions for life. Despite this, it is possible to find microorganisms and plants growing under these adverse conditions. In this environment, one of the most conspicuous biological formations are the biocrust, which are microbial communities keystone in the ecosystem functioning where they are developing, however in the Antarctica the studies of this formations are limited. We aimed to address these following questions: Who organisms to participate in the formation of the biocrusts? What is the role of biocrusts in the nutritional aspects of soils? What is the effect of biocrusts on the growth of the vascular plants? To address these questions, samples of biocrust and individuals of Colobanthus quitensis were obtained from King George Island. To identify composition of biocrust, DNA was extracted and characterized using metagenomics sequencing of 16S and ITS. Additionally, manipulative soil experiments with and without biocrusts were conducted in order to assess the role in the nutritional quality of soils as well as on the growth of C. quitensis. Our results showed high taxonomic variability in the composition of the biocrust, with dominance of proteobacteries, and cyanobacterial In relation to nutrient content levels were higher in soils with biocrusts compared to bare soil; additionally, this higher nutrient content was associated with a greater final biomass of C. quitensis. Thus, our results suggest that biocrusts have a positive impact in Antarctic plants and soils by improving nutrient content, with significant impacts in the plant Antarctic communities.

1193

A genome reduced-representation approach (3RAD) to understanding the population structure of the Antarctic toothfish in the Weddell Sea and beyond

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The Antarctic toothfish (Dissostichus mawsoni) has a critical role in Southern ecosystems as a top fish predator. There is a near total lack of knowledge of the life history and population structure of Antarctica toothfish in the Weddell Sea. Based on the hypotheses that have arisen from the Ross Sea, a possible life cycle of Antarctic toothfish comprises juvenile development on nutrient rich continental shelf areas, followed by passive transport via gyre systems to offshore sea mounts, where spawning occurs, prior to completion of the cycle as fish are passively transported back towards the coast.

Genetics approaches offer the possibility to test between population hypotheses using the metric of relatedness between individuals. RADseq methods reduce the complexity of a genome in order to highlight interindividual variation without the need for whole genome sequencing. While many variants of this approach have been developed, our group has optimized the implementation of the 3RAD approach, which addresses many of the limitations of existing RADseq approaches including cost, adapter dimer and chimera formation, and DNA quantity required.

This presentation will share the results of our development of 3RAD in Antarctic toothfish, with the goal that our approach be available for use in the community in order to address gaps in our knowledge of Antarctic toothfish genetics structure in the Weddell Sea and on a circumpolar scale.

1150

A deep look into the Photosynthetic Pico- and Nano-eukaryotic diversity across Antarctic (Ross Sea) and subantarctic waters (Campbell Plateau) of the SW Pacific sector

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Photosynthetic pico-eukaryotes (PPE) and photosynthetic nano-eukaryotes (PNE) are key components of the Southern Ocean. Traditional genomic techniques used to describe these communities tend to overlook the small phytoplanktonic fraction and hence we still know little about the composition and functionality of this component. In this work, we investigated the taxonomic composition of PPE and PNE communities in two contrasting oceanic regions: the subantarctic region of Campbell Plateau (autumn) with distinct HNLC conditions (ON vs. OFF of C. Plateau) and the oceanic and slope region of the Ross Sea, surveyed during two oceanographic voyages conducted in March 2017 and February-March 2018, respectively. We compared the molecular diversity obtained from PPE and PNE populations sorted by flow cytometry (FCM) as well as from the whole community collected in 0.8 µm filters (Filtered) using high throughput sequencing of the V4 region of 18S rRNA. We obtained a total of 5825159 sequences and 1515 Amplicon Sequence Variant (ASV) for the sorted samples. Chao1 and Shannon diversity index were overall greater for the sub-Antarctic region. Samples from the Antarctic region were dominated by 8 ASV corresponding to Ochrophyta, Haptophyta and Dinoflagellata, with the main abundance of Phaeocystis antartica and Fragilariopsis sp. While the Subantarctic region were mainly dominated by 2ASV, corresponding to Chlorophyta (mamiellales) and Haptophyta (phaeocystales). FCM-sorted samples denote a higher sequencing coverage among the PPE and PNE community compared to Filtered samples. Overall this approach allows a better understanding of the diversity of the small photosynthetic eukaryotes on the Antarctic and Subantarctic ecosystem

1262

Unraveling the core-genome of the Antarctic picocyanobacterial lineage

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Antarctic cyanobacteria are widespread in aquatic biotopes and often dominate the phototrophic biomass. Evaluation of the influence of environmental selection and historical processes on their current diversity and distribution is challenging, especially in relation to the question of endemism. Recent studies have shown that depending on taxonomic resolutions and molecular methodologies, the answer could be different.

Here, we focus on molecular traits involved in mechanisms underlying the ecological success of the picocyanobacterial lineage in Antarctica. Based on an extensive sampling of Cyanobium/Synechococcus genomes, we perform a comparative analysis to determine genes that are specific to Antarctic genomes and find the ones linked to functional adaptations.

We reconstructed the genomes of 8 strains from the BCCM-ULC Cyanobacteria Culture Collection (Liège, Belgium). 19 genomes assemblies were then retrieved from NCBI database to conduct a pan-genome analysis (5 Antarctic, 1 Arctic, and 21 non-polar genomes). Phylogenomic tree based on an alignment of sequences of 36 concatenated ribosomal proteins confirmed that the Antarctic genomes represent a distinct lineage.

From the 7286 groups of orthologous genes (OGs) defined for these 27 genomes, 1840 (25,3 %) constituted the Antarctic-specific core-genome and are mainly shared with non-Antarctic genomes. Further analyses are being carried out to analyze in more detail the core-genome, genes only found in Antarctica, gene duplication events and to determine potential selective pressures occurring on these genes. From an environmental protection perspective, in which the question of endemism is decisive, highlighting the specificity of Antarctic genomes could be determining.

1573

Characterization of the microbial community of the Dalton polynya

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The Southern Ocean plays a pivotal role in the global carbon cycle. Antarctic coastal polynyas especially represent hotspots for primary production, harbouring the highest biomass of primary producers on the continental shelf. Climatic changes in this region have potential to impact on the magnitude of the Southern Ocean to act as a carbon sink with consequences that will reverberate across global ecosystems. The Dalton polynya in the Sabrina Coast is within the most active polynyas for East Antarctica. However, the continuous input of melting freshwater from the Totten glacier has created a highly stratified environment. The effects of these changes on the composition of the microbial community and primary producers has not been examined. As such identifying the community composition and the factors influencing their distribution is of extreme importance in order to understand the role of the Southern Ocean in past, present and especially future marine biogeochemical cycle. Here we provide the first detailed characterization of the microbial communities across environmental gradients in the Dalton polynya using both molecular and quantitative approaches. High-throughput flow cytometry was applied for a quantitative integrated study of the viral, bacteria and photosynthetic communities, coupled with the sequencing of the 16s rRNA and 18s rRNA for qualitative characterization of the bacterial and eukaryotic community diversity. Preliminary results revealed how specific phytoplankton species were differentially distributed along the continental shelf. These measurements provide essential context to understand and begin to model the effect that climate change will have in this important region for East Antarctica.

1700

Genomic insight into the extent and drivers of genetic differentiation in Eudyptes penguin species and populations

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Around 8 species of Eudyptes penguins are described. There is no consensus in the exact number possibly due a recent diversification process that challenges species delimitation when there is low genetic or morphological differentiation. Eudyptes penguin species breed on several islands separated by vast open ocean extensions along Antarctic, sub-Antarctic and sub-Tropical waters. This water masses are delimitated by oceanic fronts in which drastic biotic and abiotic changes occur, leading to their conception of oceanic barriers to dispersal for several taxa. Geographical distance between breeding colonies and the presence of oceanic fronts may lead to a reduction in gene flow in Eudyptes penguin species however their contribution to population differentiation can vary depending on the species. Using SNPs we studied contemporary patterns of connectivity in five Eudyptes penguin species; Macaroni (E. chrysolophus), royal (E. schelegeli), nothern (E. moseleyi), southern (E. chrysocome) and eastern (E. filholi) rockhopper penguins. We also evaluated genetic differentiation in two groups of taxa under taxonomic debate (macaroni/royal and northern/southern/eastern rockhoppers). We found that even across vast distances, genetic differentiation among Eudyptes penguin populations within each species was low however, at least at some degree, it may be imposing a reduction in gene flow. The same is true for the presence of the Antarctic polar front separating macaroni penguin populations, in which we found two genetic clusters. Genetic differentiation was scarce between macaroni/royal penguins suggesting they represent a single evolutionary unit. Conversely, genetic differentiation between northern/southern/eastern rockhoppers supports the designation of three separated species.

1032

Introducing POLA$_3$R, an online portal to discover microbial polar ’omics data

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High throughput DNA sequencing techniques have completely revolutionized microbial ecological research at the poles. Like museum collections, the vast wealth of microbial ‘omics data that these studies generated needs to be archived in a way that makes the data Findable, Accessible, Interoperable and Reusable (FAIR) for future research. However, the complexity of ‘omics data, which typically includes geographical and environmental components besides the sequencing data, as well as laboratory protocol metadata, poses serious challenges for data archiving on international nucleotide and biodiversity databases such as GenBank and Global Biodiversity Information Facility (GBIF). The Microbial Antarctic Resource System (mARS) represented a first step to achieve this in an Antarctic context. But now we are expanding that scope to all Polar regions. Therefore, we introduce the Polar ’Omics Links in Arctic-Antarctic-Alpine (A$_3$) Research, or POLA$_3$R for short. On this online platform datasets that are enriched with metadata and environmental information are made publicly accessible, and are linked to the associated publications and the sequences on nucleotide databases such as GenBank. To allow interoperability with other systems, the portal is designed to operate between different data archiving standards, such as the Minimum Information on any (x) Sequence (MIxS) as well as DarwinCore. Datasets that are listed on POLA$_3$R are also registered on GBIF to increase their discoverability. As such, POLA$_3$R aims to provide a hub for the polar scientific community, where you can discover high quality and complete molecular biodiversity data.

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Biogeographical patterns in Southern Ocean near-shore marine benthic mollusks

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The biogeography of the Southern Ocean (SO) biota and its current bioregionalization are the consequence of major tectonic, oceanographic and climate changes since the Mesozoic. Here, we present biogeographical comparisons in different near-shore benthic mollusks with contrasting developmental modes across the SO. Through phylogenetic and phylogeographic approaches we aim to further understand the role of historical and contemporary processes in the recorded evolutionary patterns. We include direct developers (Laevilitorina, Margarella and Siphonaria) and broadcast-spawners (Nacella, Mytilius and Aequiyoldia). We estimated uncorrected p-distances, divergence time analyses and maximum parsimony genealogies. Very levels of genetic diversity characterize the analyzed mollusks as a consequence of the Quaternary glacial processes that deeply affected their population sizes. Similarly, most of the analyzed groups (Nacella, Laevilitorina, Aequiyodlia, Margarella) showed high degree of genetic divergence between Antarctic and sub-Antarctic provinces supporting the role of the Polar Front as an effective biogeographic barrier. The effective separation of Antarctic and sub-Antarctica lineages occurred less than 10 Ma, long after the physical separation of the continental landmasses or to the initiation of the Antarctic Circumpolar Current. Surprisingly, direct developers (M. viocalea, S. lateralis, S. fuegiensis) exhibited high levels of genetic identity between geographically distant sub-Antarctic provinces supporting the role rafting as an important biogeographic mechanism. In contrast, broadcast-spawners (Nacella and Aequiyoldia) showed marked genetic differences across the sub-Antarctic. Finally, current biogeographical patterns in SO mollusks are not related to particular groups or developmental modes but to historical oceanographic/climatic processes, as well as contemporary ones including the likelihood of long-distance dispersal.

1421

Genomes and transcriptomes help elucidate the evolutionary drivers and biodiversity of Antarctic marine invertebrate fauna

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Our understanding of marine invertebrate fauna found on Antarctic continental-shelf regions has changed dramatically due to the application of molecular tools. There is far more biodiversity than previously recognized and genetic admixture around the continent and to other regions is better characterized. We extended these earlier studies with RAD-tag based SNP (single nucleotide polymorphism) efforts to study evolutionary patterns of marine invertebrate adaptation and dispersal in the Southern Ocean. Currently the primary hypothesis explaining such diversity invokes glaciation and genetic drift as forces of speciation. To test this hypothesis, we are using transcriptomes and genomes to look for signatures of selection versus genetic drift. We have sequenced more than a dozen transcriptomes from Antarctic organisms (with an emphasis on echinoderms). These transcriptomes are not unusual compared to transcriptomes from more temperate animals, but genes of interest have been identified. For example, putative antifreeze proteins (large glycoproteins) occur in taxa such as Odontaster validus. Moreover, genomes of commonly studied Antarctic marine taxa (including the echinoderms Sterechinus neumayeri and Astrotoma agassizii) are being sequenced. Although an initial 10X Genomics sequencing approach was not successful at producing high quality genomes (presumably due to heterozygosity issues with the assembler), we are scaffolding these runs with PacBio data. The resulting genomes will be paired with RAD-based Single Nucleotide Polymorphism (SNP) data and sliding window analyses to identify genomic regions that have been subject to positive selection or pronounced admixture. Additionally, we will report on the taxa sequenced and the availability of these resources.

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Morphological innovations in brittle stars driven by sub-Antarctic glacial refugia

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The Pleistocene glacial period has been widely hypothesised to be challenging for benthic fauna to persist in the Southern Ocean. One of the key ecological disturbances at the time was that most continental shelf habitats were repeatedly eroded by ice sheet expansions. While limited molecular data has hinted where benthic fauna might have persisted in ice-free areas (i.e. refugia) in the Southern Ocean, how these past extreme environmental changes influenced evolutionary processes remains unclear. Since their recent speciation in the late Pleistocene, new genetic (partial cytochrome c oxidase subunit I) and genomic (double digest restriction-site associated DNA) data suggest the Antarctic brittle stars Ophionotus victoriae persisted in deep sea refugia, while O. hexactis persisted in sub-Antarctic refugia. Incomplete lineage sorting between O. victoriae and O. hexactis was also detected, highlighting that the time in isolation between deep sea and sub-Antarctic refugia appears to be insufficient for monophyly to be established under coalescence. Ecological shifts related to environmental fluctuations within sub-Antarctic refugia might have promoted morphological innovations in O. hexactis (an increase in arm number and a switch to brooding from broadcast spawning). Our results contribute to a better understanding of how environmental extremes could influence how species evolve and diversify and also highlight the resilience of Southern Ocean fauna through ecological adaptation.

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Hind-wing morphology in the sub-Antarctic diving beetle Lancetes angusticollis (Curtis, 1839) (Coleoptera: Dytiscidae)

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The diving beetle Lancetes angusticollis is found in lakes in southern South America and in South Georgia. The geographical isolation of these populations suggests they have been separated on sufficiently long timescales to permit the evolution of adaptive changes in morphology. One of the more commonly reported morphological variations associated with island isolation is the reduction of wings, generally linked to different requirements in terms of energy reserves and lower predation pressure. We tested the hypothesis that the South Georgian populations of L. angusticollis would have reduced hind wings in comparison with their mainland counterparts. To test this, we documented geometric morphometrics, analyzing the data with Principal Component Analyses, to assess body and wing size and shape. Beetles from South Georgia had significantly longer heads, elytra and hind leg lengths, and shorter pronotum length, although they did not differ in overall body length. The centroid size did not vary, meaning that the overall size of the wings was not different, but the calculated wing loads showed that hind wings were of different shapes, with the main differences being in the costal, jugal and posterior margins of the wings along with the cubital cells. However, all of these observed differences in wing shape were subtle and do not clearly link with the hypothesis being tested. Based on this study, we suggest the most likely reasons for the slight differences in morphology found to be founder effect and genetic drift.

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Phylogeography of the winged Antarctic midge Parochlus steinenii (Gercke, 1889) (Diptera: Chironomidae: Podonominae)

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The chironomid midge Parochlus steinenii, one of only two holometabolous insects occurring in Antarctica (South Shetland Islands), is also found around lakes in southern South America and in sub-Antarctic South Georgia. Previously published evidence, based on a small number of sequences of the 28S rDNA gene, inferred divergence between South American populations and those in South Georgia and Antarctica around seven million years ago. To further test the divergence hypothesis, we extracted DNA from over 150 specimens of P. steinenii from 13 different lakes across most of the species' known range. In addition to obtaining further 28S sequences, we expanded the analysis to include the mitochondrial COX1 gene. No variation was present among the new 28S sequences, in contrast to the previous study. However, sufficient variation was present amongst the COX1 sequences to permit phylogeographic analysis and the generation of a haplotype network and molecular phylogeny. These analyses confirm the presence of distinct clades from each region and corroborate the deep genetic separation of South American from South Georgian and Antarctic clades.

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A global phylogeny of the shrimp family Benthesicymidae: from Equator to Subpolar areas and from benthic to mesopelagic.

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Benthesicymidae is a family of pelagic shrimps distributed across all principal oceanic biotopes, within wide geographical (from Equator to subpolar areas of both Hemispheres) and depth (5 km) ranges. Benthesicymidae provide a unique opportunity to examine how evolutionary trends mirror so different environmental factors and how morphological traits favor colonization of these principal oceanic biotopes. We present the first phylogenetic study to include all species of the family (all 37 valid species), which is based on six molecular markers and 105 morphological characters. Molecular methods provide better resolution of deeper nodes and generally higher support of the clades, while morphological methods allow analyses of all valid species of the global fauna. We suggest a new phylogenetic systematics of the family including two new subfamilies and five new genera. We analyzed morphological traits within benthic and pelagic clades and showed supremacy of copulatory structures. We show that the petasma greatly evolved both in the benthic and pelagic clades, while thelycum significantly evolved only in the pelagic clades. We propose a model explaining this difference. Along with previous studies, our results confirm the idea that the elaboration of the copulatory structures is a key to successful colonization of the pelagic realm. We also discuss possible pathways of various clades of Benthesicymidae into medium and great depths, into low and high latitudes.

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A phylogeny of krill (Crustacea: Euphausiacea): pathways into high latitudes, near-shore habitats, and deep sea

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The order Euphausiacea, widely known as krill, is a commercially and ecologically important group of marine crustaceans, dominating in the World Ocean and in the Antarctic. Krill serves an important role in the sequestration of organic carbon from the upper ocean layers and it has been shown that the sinking of krill fecal pellets and moult casts are the primary agents of the downward flux of carbon. We present a phylogenetic study of the global krill fauna based on molecular markers (4) and morphological characters (168) and scrutinize the taxonomy of the whole order. We revealed groups of morphological characters, which are likely coupled with same biological role and thus interlinked evolutionarily. We analyze the evolutionary pathways of the clades into main oceanic biotopes and discuss morphological adaptations most likely coupled to this process. We pay a special attention to pathways into extreme biotopes: high latitudes of the Arctic and the Southern Ocean, near-shore habitats, and the deep sea.

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Applying genomic tools to answer phylogeographic questions for Antarctic benthic marine invertebrates.

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Benthic invertebrates living in the marine continental shelf environment in Antarctica show remarkable diversity. Historically, studies employing mitochondrial genes or gene fragments (e.g., amplicons from cytochrome c oxidase subunits I and II, 16S, cytochrome b) described numerous unknown, yet genetically distinct, lineages in several invertebrate taxa including isopods, sea spiders, echinoderms, and nemerteans. Despite this increased appreciation of diversity from the region and the early application of molecular tools to study them, we are still trying to explain bigger picture phylogeographic patterns around the Antarctic and the factors that produce such patterns. Efforts to improve our knowledge of Antarctic phylogeography include the application of new and novel genomic tools, along with increased sampling efforts around the continent. In this, we are improving our understanding of patterns of biodiversity around the continent and throughout the Southern Ocean. The development and application of new molecular methods, such as whole genome scanning techniques (e.g., RADSeq) and mitogenomics on organisms from the region, is allowing us to address questions relating to scenarios that may have impacted the current distributions of Antarctic shelf marine fauna. In this presentation, we will discuss our ongoing work that continues to investigate major these patterns around the continent for a number of organisms, including mitogenomics in sea spiders and population genomics of the pycnogonid Nymphon australe and the nemertean Parborlasia corrugatus. We expect that knowledge of organismal diversity through the implementation of additional ‘omic studies that include increased sampling efforts will have tangential impacts throughout Antarctic biological research efforts.

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Grasping the diversity of the Doris ‘kerguelenensis’ species complex within the Southern Ocean

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The Southern Ocean benthic sea slug, Doris ‘kerguelenensis’, was long-thought to be a single, widespread species that showed reduced dispersal potential. Belonging to the Dorididae family, this slug is a direct-developing, simultaneous hermaphrodite that can only crawl along the seafloor as an adult. More recently however, a combination of mitochondrial and nuclear DNA sequencing combined with metabolomics, has revealed a multitude of highly divergent lineages within that ‘species’, signalling an explosive marine adaptive radiation comprising of over 32 putative species. This radiation was thought to be caused by a unique combination of selection and allopatry facilitated through millions of years of episodic glacial cycles. This resulted in the segregation of the animals into smaller, reduced populations, which in turn, increased vulnerability to predation pressure. Through Sanger sequencing of the single mitochondrial gene, Cytochrome Oxidase I (COI), this project has generated a single gene phylogeny consisting of over 1,000 samples, resulting in up to 70 putative mitochondrial lineages. Using available transcriptomic data, we will next characterise and confirm the placement of these mitochondrial lineages within the D. ‘kerguelenensis’ species complex as well as incorporate secondary metabolite profiles into this phylogenetic reconstruction in order to further delimit species. By resolving this phylogeny and mapping the distribution of these metabolites across the topology of the phylogeny, we will be able to produce important genetic resources that can be used in future work.

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Evidence of strong small-scale population structure in the Antarctic freshwater copepod Boeckella poppei in lakes on Signy Island, South Orkney Islands

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Environmental conditions were particularly severe during the Last Glacial Maximum, altering the distribution of the Southern Hemisphere biota, particularly at higher latitudes. The copepod Boeckella poppei is the only macroscopic continental invertebrate species known to be distributed today across the three main biogeographic regions in Antarctica as well as in southern South America. Signy Island (South Orkney Islands) is a unique location for the study of Antarctic freshwater ecosystems due to its location and geographic isolation; it contains 17 lakes in several low altitude catchments. We conducted phylogeographic and demographic analyses using the cox1 gene on 84 individuals of B. poppei from seven lakes across Signy Island. We recorded low levels of genetic diversity and a strong genetic differentiation signal between the eastern and western valleys within the island. Phylogeographic structure and demographic inference analyses suggested at least one asymmetrical dispersal event from west to east. Demographic inference detected a strong signal of population growth during the deglaciation process, which may have followed either (1) a strong genetic bottleneck due to a reduction in population size during the last glacial period, or (2) a founder effect associated with postglacial recolonization of Signy Island from elsewhere. The genetic architecture of this island's populations of B. poppei shows that historical events, rather than continuous dispersal events, likely played a major role in the species' current distribution. Finally, our study considers possible mechanisms for dispersal and colonization success of the most dominant species in the Antarctic freshwater community.

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Towards an understanding of genetic structure among Lepidonotothen squamifrons (Teleostei: Nototheniidae) populations distributed around the Southern Ocean

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Lepidonotothen squamifrons is among the notothenioid fish that are widely distributed around the Southern Ocean. This distribution have created number of taxonomic issues, which still exist regardless of the number of research that attempted to solve them. The present study aimed to address this problem by investigating genetic structure among L. squamifrons populations that are found in the three ocean sectors of the Southern Ocean. The genetic structure was assessed by analysing the mitochondrial COI gene and six microsatellite markers. The COI data set produced 13 haplotypes and four of these are shared while nine are private. Two of the shared haplotypes consisted of specimens from the Atlantic Ocean only; one was shared between the Atlantic and Pacific Oceans specimens; and the last haplotype consisted of the Indian Ocean specimens only. Analyses of genetic differentiation using AMOVA, for both COI and microsatellite data sets, showed higher genetic variations within specimens of the same locality. A haplotype network tree revealed that Atlantic Ocean specimens contributed more towards these variations as specimens in this ocean were clustered in different haplotypes. However, the observed genetic variations do not represent the presence of two species within this population. The present study further showed that there is gene flow between Atlantic and Pacific Oceans populations, while Marion Island population (representative of Indian Ocean) differ slightly from these two oceans.

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Environmental drivers of diversity in Antarctic terrestrial plants and animals: using genomic approaches to discover broad-scale patterns

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Understanding the drivers of Antarctic biodiversity patterns is crucial if we are to mitigate the effects of rapid environmental change. Pressing questions remain largely unanswered including: where are biodiversity hotspots in Antarctica, and are Antarctic terrestrial populations biologically isolated or well connected? The rapid development of genomic techniques provides exciting new opportunities to address these and related questions. In a broadscale new research project, we are using environmental DNA (eDNA) metabarcoding analyses of soil, combined with spatial environmental analyses, to investigate the drivers of diversity in terrestrial communities over both local (10s to 100s km) and continental scales. In this talk, we will present an overview of the progress of the project to date, including results of preliminary eDNA metabarcoding analyses of soils from East Antarctica (including Larsemann and Vestfold Hills), testing whether geothermal areas support higher biodiversity than non-geothermal areas, on local scales. Geothermal areas have been proposed to have helped life to survive Pleistocene glacial maxima. If they have, we expect to see higher biological diversity close to geothermal areas, and lower diversity further away. Furthermore, we present a summary of methodological trials aimed at optimising Antarctic soil eDNA analyses. Our findings will shed light on the processes that have shaped – and continue to shape – the evolution and diversity of Antarctic terrestrial communities.

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Diversity, structure and functions of Antarctic vascular plant rhizosphere microbiomes from the central maritime Antarctic

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Deschampsia antarctica and Colobanthus quitensis are two native Antarctic vascular plants resisting severe conditions of maritime Antarctic, while the mechanisms of its adaptation are still debated. Microorganisms in rhizosphere soil have a significant role in plants` adaptation and distribution.
The rhizosphere microbiomes of Deschampsia antarctica and Colobanthus quitensis, from the central maritime Antarctic were studied. Rhizosphere microbiomes of D. antarctica had high taxon richness (Shannon 5.2–9.3), while of C. quitensis had much lower diversity (Shannon 0.9). The bacteria in the rhizosphere communities of the hairgrass mainly affiliated to Proteobacteria, Bacteroidetes and Actinobacteria. Rhizosphere of pearlwort was inhabited by Actinobacteria. The microbiomes included high proportions of unique OTUs (19.6% to 63.3%) and there was high heterogeneity between the samples at the OTUs` level. Soil parameters were not the reason for the heterogeneity, and it can be caused by microscale effects of environmental conditions such as edaphic or microclimate factors.
Metabolic predictions in silico using PICRUSt 2.0 indicated that the microbiomes of D. antarctica were similar by the predicted functional repertoire, despite the overall differences in diversity. About 4.3 10.7% of MetaCyc ontology pathways of the microbiomes were involved in degradation of polymeric and aromatic substrates. KEGG orthologs involved in siderophores (0.08–0.15%), indole acetic acid (0.2–0.5%) and ACC-deaminase synthesis (0.03–0.05%) were among the predicted functional groups. The data obtained indicate that these communities are involved in the primary processes of soil development in the central maritime Antarctic and may be beneficial for the growth of Antarctic vascular plants.

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A first assessment of genetic variability of Lyallia kerguelensis an endemic species of Kerguelen islands: should this species be considered as threatened?

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Genetic diversity is well-recognized as a major determinant to species adaptation and resilience. Although sub-Antarctic plant species are facing changes in environmental conditions (e.g. an increase in variability of rainfall), few studies have assessed the amount and population patterns of their genetic variability. Genetic studies were carried out on L. kerguelensis, a strict endemic species from Kerguelen Islands, which distribution is scarce, extremely fragmented and restricted to fellfield or moraines. Most populations do not contain more than a hundred or even dozens of individuals. This species has possibly suffered from herbivory pressure caused by the recent introduction of rabbit. The following questions were addressed: i) what is the ploidy level of this species? This question matters since polyploidy can drive rapid adaptation. ii) what is the level of genetic diversity within populations and what is the population genetic structure across the whole Kerguelen archipelago? Microsatellite markers were de novo developed. Fifteen of them were used to assess the level of genetic polymorphism in 20 populations across Kerguelen Islands. Four whole chloroplast genomes from four populations sampled at remote locations were also sequenced. Original data showed this species is octoploid and displayed an uncommonly low genetic diversity at microsatellite markers. Only three SNP were found among the ~156 Kbp of the chloroplast genome. Results strongly suggested L. kerguelensis has undergone a very strong and recent (possibly at LGM) and/or protracted demographic bottleneck. Together with other demographic and ecological observations, this result questions whether this species should be considered as threatened

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Phylogeography of Antarctic Soil Invertebrates

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Terrestrial Antarctic ecosystems are populated by diverse yet understudied invertebrate communities, essential for healthy ecosystem functioning. As healthy ecosystems are built from the ground up, it is essential to understand how environmental and biogeographic conditions can influence contemporary distribution patterns. Soil mite, springtail and nematode specimens collected from islands off the Antarctic Peninsula between 2014-2016 will be analysed using comparative phylogeographic techniques that combine genetic and geographical datasets to capture their distribution and evolutionary histories. Soil communities from temperate Australian islands along a comparable latitudinal transect with different biogeographic histories will help disentangle the biogeographic, climatic and environmental drivers of soil faunal communities. Comparing gene flow within species between remnant (e.g. isolated by rising sea-levels) and pioneering populations (dispersers to off-shore islands) will highlight the factors that enable soil fauna to overcome isolation and ecosystem fragmentation. In summary, detailed analysis will also reveal the drivers of distribution at the a) local scale; environmental and biotic variables, b) regional scale; climatic influences and gene flow; and, c) temporal scale; evolution and dispersal in Antarctic and temperate invertebrate communities. These will improve our capabilities of conserving these essential ecosystem operators under mounting pressures from local and global environmental change.

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Hidden diversity in Antarctica

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The Southern Ocean is one of the most isolated marine ecosystems, characterized by high levels of endemism, diversity, and biomass. Ascidians are among the dominant groups in Antarctic benthic assemblages, thus recording the evolutionary patterns of this group is crucial to improve our current understanding of the assembly of this polar ocean. We studied the genetic variation within Cnemidocarpa verrucosa sensu lato, one of the most widely distributed abundant and studied ascidian species in Antarctica. Using a mitochondrial and a nuclear gene (COI and 18S), the phylogeography of fifteen populations distributed along the Antarctic Peninsula and South America (Burdwood Bank/MPA Namuncurá) was characterized, where the bimodal distribution of the genetic distance suggested the existence of two species within the nominal C. verrucosa. When re-evaluating morphological traits to distinguish between genetically defined species, the presence of a basal disc in one of the genotypes could be a morphological trait to differentiate the species. These results are surprising due to the large research that has been carried out with the conspicuous C. verrucosa with no differentiation between species. Furthermore, it provides important tools to distinguish species in the field and laboratory. But also, these results give new insights to patterns of differentiation between closely related species that are distributed in sympatry, where the permeability of species boundaries still needs to be well understood.

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How the Genus Eusirus amphipods evolved and speciated in the Antarctic

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Antarctica has been subjected to different climatic changes in the past requiring the marine fauna to either adapt to novel environmental conditions, migrate to better conditions or become extinct. Currently, warming of Antarctica is happening at an unprecedented rate. Understanding how these organisms have managed to survive in the past will thus allow us to predict their possible responses to future climate changes. Here, the amphipod Genus Eusirus will be used as model organisms since these amphipods are very diverse and knowledge on their ecology and biogeography is still very limited. In this study, molecular, morphological and ecological data of Eusirus will be collected. Because no reference genome exists for this group, we will use a Next generation sequencing approach to obtain the complete mitochondrial genome (mitogenome) of these amphipods. Draft mitogenomes have been assembled and annotated from skim sequencing for two Eusirus species. From these mitogenomes, we designed primers for long-range PCRs to amplify the entire mitogenome in several pieces. Complete mitogenomes will allow us to estimate genetic divergence amongst different species and check for specific temperature adaptations of mitochondrial genes. The obtained mitogenome data will also provide better supported phylogenies for reconstructing evolutionary history of Eusirus. In order to get a better understanding of adaptive and/or non-adaptive processes which led to the current diversity of Eusirus amphipods, we will explore how morphological and ecological diversity are partitioned along the resulting phylogeny, concurrently with potential changes in lineage diversification through time.

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Are genetic and species diversities turnover correlated in lichen-forming fungi and their photobionts along a latitudinal gradient in the Transantarctic Mountains?

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Lichens are the most diverse group of macroscopic organisms in Continental Antarctica. Their occurrence is known up to 86ºS and reduced communities are known from most ice-free rocky areas visited in the Transantarctic Mountains. However, little is known about the processes behind the assembly of those communities, although random dispersal has been proposed as the likely main driver. The study of the species-genetic diversity correlation and the turnover at both diversity levels across space may shed light on the main processes shaping communities when a neutral marker is used to measure genetic diversity. We have sequenced the putative neutral internal transcriber spacer (ITS) of both myco- and photobionts (Trebouxioid taxa) more than 700 lichen samples from 5 regions in continental Antarctica along a latitudinal transect from 76° S to 84° S. Further, we delimited operational taxon units in both taxa using an algorithm based on genetic distances (ABGD). Results pointed to a decoupled turnover between mycobionts and photobionts, with a high turnover of species and ITS haplotypes in the former, but not so pronounced in the latter.

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Phylogenetic diversity of lichen symbiotic fungi inhabiting the Continental Antarctica

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Lichen symbioses have been very successful in colonizing a broad range of extreme environments; one of these is the Antarctic continent. Indeed, lichens – lichen forming fungi – are the most diverse and visually common eukaryotic organism followed by mosses in all Antarctic regions. Since the phenotypic features are highly plastic in lichens including non-lichenized fungi, we used DNA sequence based sample identification to resolve their diversity and evaluate endemism in terrestrial mycobiota of continental Antarctica (Victoria Land). We used the internal transcribed spacer – ITS – sequences as this is the universally accepted DNA barcodes of fungi including lichens. We sequenced and analyzed a total of 54 samples from 9 localities along the Victoria Land coast line representing different genera of broad phylogenetic range (Order to Family) . While some widespread morphospecies e.g. Rhizoplaca melanophthalma were monophyletic, the others, for example, Umbilicaria aprina, U. decussata, Physcia caesia and P. dubia appear polyphyletic. Moreover, our results underline significantly higher endemism in the continental Antarctica than previously assumed. In addition, our study provides a baseline for further investigations on tracing the migratory route of Antarctic populations of widespread lichen species especially during past periods of excessive warming. The sample identification based on morphological and chemical features was confirmed with the ITS sequences.

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The brooding brittle star Astrotoma agassizii does not always brood as it is a species complex: genomic and life history characters provide clues to a turbulent evolutionary history

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The Southern Ocean holds a wealth of diversity that is particularly rich along the shallower continental shelf regions of Antarctica, Kerguelen Plateau and the Scotia Arc including the Patagonian Shelf. Cryptic diversity is not uncommon among species from these regions, hugely increasing the actual diversity and richness compared to the recognised diversity. The cryptic diversity can in part be explained by vicariance, or allopatric speciation due to large distances between suitable habitat, strong oceanographic features such as the Polar Front that at least partially inhibit gene flow, and historical events fragmenting populations. A possible example of population fragmentation is the bulldozing of benthic life off the continental shelf by grounded glaciers during the last glacial maximum leaving few isolated refugia in which pockets of the previous assemblage survived. The large and charismatic brittle star Astrotoma agassizii is one such example of a species distributed across the Southern Ocean and in which there has been evidence of cryptic diversity. New evidence is suggesting the diversity is substantially greater than recognised in previous work, with complexity identified in life history traits and morphology that add a new dimension to understanding the evolutionary history of this enigmatic species group.

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Antarctic coastal plankton metabarcoding: a long term and low-cost approach to monitor intra and inter-annual dynamics by taking advantage of research base desalination plant filters

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One of the main requirements for a sound biological monitoring is the availability of long term and possibly temporal fine-grained data. This is often difficult to be achieved, especially in Antarctica, due to the existing logistic and economic constraints. In the framework of the Italian PNRA project "TNB-CODE" (Terra Nova Bay barCODoding and mEtabarcoding of Antarctic organisms from marine, terrestrial and limnetic environments), we have focused on the use of filters of the Mario Zucchelli base desalination plant to monitor coastal plankton communities. Filters of different mesh sizes are used to decrease the amount of organisms and debris before desalination processes and are in use continuously to be changed just before clogging. Thus, they naturally collect the spectrum of species present in the surrounding water masses. Analysis of data from the desalination plant diary from 2001 to 2019 showed a consistent higher rate of filter replacement in coincidence with the phytoplanktonic blooms. Molecular data obtained from 5 µm mesh filters sampled during January in 2012 and 2013 demonstrated the ability of metabarcoding in characterising nanoplankton communities, highlighting both inter- and intra-annual dynamics, even when changes occur in a few days. These fine-grained data would not have been possible by using standard sampling approaches as they would have required a continuous sampling at sea. This method, by combining a cost-effective sampling and molecular techniques, represents a viable solution that guarantees the acquisition of long term data for coastal plankton monitoring.

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Diversity, function and biogeography of the gut microbiota of the antarctic heart urchin (Spatangoida) Abatus agassizii

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Abatus agassizii is an irregular sea urchin species that inhabits shallow waters of South Georgia and South Shetlands Islands, and feeds by ingestion of the surrounding sediment. Despite the low complexity of its feeding habit, it harbors a long and twice-looped digestive tract suggesting that it may host a complex bacterial community. We focused two A. agassizii populations at the south of the King George Island in the West Antarctic Peninsula. Through a metabarcoding approach targeting the 16S rRNA gene, we characterized the Abatus microbiota composition and putative functional capacity, evaluating its differentiation among the gut content and the gut tissue in comparison with the external sediment. Additionally, we aimed to define a core gut microbiota between A. agassizii populations to identify potential keystone bacterial taxa. Our results show that A. agassizii acts as a selective filter of the diversity and the composition of the surrounding sediment bacterial community, at both genetic and predicted functional levels. Specific bacterial taxa, belonging mostly to Planctomycetacia and Spirochaetia, were differently enriched in the gut content and the gut tissue, respectively. Predictive functional profiles revealed higher abundance of specific pathways, as the sulfur cycle in the gut content and the amino acid metabolism, in the gut tissue. Further, the definition of a core microbiota allowed the identification of potential keystone taxa assigned to the Desulfobacula and Spirochaeta genera as potentially host selected. Finally, by exploring the genetic structure of these keystone taxa in other Abatus species we revealed evidence of biogeographic patterns.

Out from Antarctica: Population genetics suggest recent diversification in the monogeneric family Harpagifaridae (Nototheniidae) along the Southern Ocean.

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Notothenioid fishes dominate Antarctica in diversity, abundance and biomass since the local extinction of most of the Eocene ichthyofauna. From these, the monogeneric family Harpagiferidae represents an interesting biogeographical model. According to the current taxonomy, this genus includes a single Antarctic species, Harpagifer antarcticus, restricted to the western Antarctic Peninsula and several shallow-water sub-Antarctic species, geographically assigned to southern South America, Falkland/Malvinas , South Georgia, Marion, Crozet, Kerguelen and Macquarie islands. Moreover, Harpagifer species exhibits a Pleistocenic divergence (1.7, 0.8Ma) between South America and Antarctica, being more recent than the ones recorded in marine benthic invertebrates, macroalgae and even other notothenioids fishes. Such results suggest that the separation of the Antarctic and sub-Antarctic linages could be related to recent dispersal events. Here, we analyzed >5,000 GBS-SNPs and COI sequences obtained from 260 individuals from seven species of Harpagifer in the Southern Ocean. Our main results suggest the presence of three genetic groups: Antarctica (Antarctica, South Georgia, Signy Island), South America (Patagonia, Falkland/Malvinas Islands) and sub-Antarctic Islands (Kerguelen, Marion). Levels of genetic distance between the recorded groups were surprisingly low, and it was not possible to identify significant evolutionary units. Patterns of genetic structure here recorded seems to be associated to microevolutionary processes (i.e. local adaptation) than historical divergence. Assuming the Antarctic origin of Harpagifer, our results suggest that long-distance dispersal played an important role in the recent Quaternary biogeography of Harpagifer from Antarctica to sub-Antarctica, a process that was followed by local adaptation processes.

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An integrated study of three limno-terrestrial Tardigrade species groups, Eutardigrada: Mesobiotus, Acutuncus and Heterotardigrada: Pseudechiniscus, in Antarctica show ancient origins, strict spatial scales and morphological plasticity to environmental factors.

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Antarctica's long history of isolation and glaciation has led to the fragmentation and adaptation to extreme environments of its surviving biota, creating the high endemism seen in Antarctica today. Antarctica is divided into East and West continental Antarctica (separated by the Transantarctic Mountains), and the Maritime Antarctic (Antarctic Peninsula and Scotia Arc) separated from Continental Antarctica by the Gressit Line, with the geological history differing significantly between these areas. There is a striking difference in species composition between Continental and Maritime Antarctica in multiple invertebrate groups, however this has yet to be shown in tardigrades. Tardigrades are an ancient lineage with a cosmopolitan distribution. They have developed physiological adaptations enabling them to survive in extreme environments, and they are a particularly important component of the depauperate Antarctic terrestrial fauna. This study performed an integrated analysis of the 18S and COX1 gene regions with morphological characteristics from multiple areas and habitat types of the Antarctic continent including the Maritime, East and Transantarctic regions. To test for population differences between biogeographic areas three species groups were used, Eutardigrada (Mesobiotus and Acutuncus) and Heterotardigrade (Pseudechiniscus). Phylogeographic analysis using both Maximum Likelihood and Bayesian methods has shown genetically distinct populations between biogeographic zones, with haplotype networks showing little interaction across populations. Molecular dating has shown these separation events to have occurred approximately 40Ma, pre-dating geographic isolation and the last glacial maximum. Morphological analysis between differing habitat types of genetically identical populations has shown significant differences indicating a plasticity to environment independent of speciation.

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Mapping the microbial diversity of the South Pacific

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Marine microbes are ubiquitous, both phylogenetically and functionally diverse and are key regulators of marine biogeochemical pathways. High resolution baseline census datasets are an important resource towards understanding the identity and function of marine microbes, but these datasets are scarce in the Southern Hemisphere. This is especially true for microbial surveys that include both vertical and latitudinal distributions and are accompanied by corresponding contextual information vital towards microbial ecology and biogeography studies. We present a methodologically standardised, phylogenetic amplicon sequencing dataset describing Bacteria, Archaea and microbial Eukarya assemblages from a latitudinal transect along the South Pacific. Samples are collected from eight depth points from surface to bottom waters every 0.5° latitude from 0° to 66°S along the GO-SHIP P15S sustained hydrographic section. The sequence data covered a wide range of key oceanographic fronts and water masses and are linked to an extensive set of globally standardised, publicly available physical and chemical oceanographic contextual information. The 1032 microbial samples have allowed us to visualise the microbial ecosystem structure of the southern Pacific basin, provide a benchmark against which we can assess assemblage changes especially towards the effects of climate change, as well as validate and constrain oceanic models. In addition to enriching existing global oceanic observations, this dataset harbours an immense array of potential. We envision that this dataset, when complemented with other global efforts such as GEOTRACES, will be a powerful tool aiding in filling many knowledge gaps of the unseen microbial biodiversity in the Southern Hemisphere.

SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 33

THE ANTARCTIC SEAFLOOR – ECOSYSTEM INTERACTIONS AND ENVIRONMENTAL DRIVERS OF CHANGE

INTERNATIONAL SCIENCE COUNCIL
SCAR
SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

Jodie Smith
Alix Post, Narissa Bax, Huw Griffiths

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Macroalgal community variation correlated with annual sea ice cover along a 450 kilometer latitudinal gradient on the central western Antarctic Peninsula

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Macroalgal forests dominate hard benthos in shallow waters along the northern portion of the western Antarctic Peninsula (WAP). Macroalgal biomass and species richness decline dramatically between southern Anvers Island and northern Marguerite Bay but observations in this gap have been limited to a few qualitative reports from the 1970s. We hypothesized that this pattern can be correlated with annual sea ice coverage patterns that govern light availability. We used satellite imagery of annual sea ice duration and extent as well as water turbidity during ice-free periods to identify 14 study sites that differed in ice coverage but were similar in terms of turbidity along the central WAP between the Joubin Islands west of southern Anvers Island (S 64° 46.4’) and the Terra Firma Islands in Marguerite Bay (S 68° 41.5’). Divers video recorded benthic organisms continuously on replicate vertical transects between 40 and 5 m depths with horizontal transects at every 5 m depth interval along each vertical transect. Macroalgae and invertebrates were collected by hand and airlift for species determinations and for both fatty acid and stable isotope food web analyses. As expected, community composition varied markedly with annual sea ice coverage, ranging from lush macroalgal forests at the lowest annual ice coverage to communities with no fleshy macroalgae where annual sea ice coverage was maximal. Combined with the satellite record and sea ice models, these data should allow predictions of how Antarctic benthic communities have and will continue to change with changes in annual sea ice.

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A submerged volcanic cone in Deception Island (Antarctica) – Benthic communities and proximal volcanism in a rapidly changing sedimentological environment

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Deception Island (DI) is amongst the most active volcanoes, with >20 explosive eruptions in the last two centuries. DI's caldera-forming eruption, a volcano-climatic event with hemispheric impact occurred 3980 ± 125c.y. before present, is the largest eruption documented in Antarctica during Holocene. Mortality of benthic organisms occurred by eruptions in 1967, 1969, 1970, with very low abundances from 1967-1973. Volcanic activity post-caldera-forming comprises many scattered eruptive vents across the island. A submarine volcanic axis with several volcanic cones is observed within the caldera, and volcanic edifices, morphologically well-preserved in the southern part of the bay raise from the seafloor up to >50 m. A multidisciplinary team sampled one of the submerged volcanoes, Stanley Patch (SP), in Port Foster (PF). Geophysical data allocated the volcano and characterized its morphology and inner structure. Direct sampling by SCUBA provided sediment and rocks, and photographs/video images of benthic organisms and landscape. Morphology of SP cone and textural characteristics of pyroclastic rocks (vesiculation, bubble shape) indicate an explosive volcanism origin, and fits with the post-caldera magmatic trend. A sediment core from the crater (4 cm Ø, 8 cm length) was collected for sedimentological, geochemical and geochronological analysis. Antarctic climate and seasonal sea ice, together with organic degradation due to high sedimentation rates, explain low TOC data. SP, and the whole PF, provide a unique, great natural laboratory for benchmarking the reestablishment of benthic communities on a volcanological-influenced shallow marine environment, offering relevant data for future studies evaluating global change effects on Antarctic seabed.

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Towards quantifying three key negative feedbacks on climate change; blue carbon gains from sea ice, ice shelf and glacier losses

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Diminishing prospects for environmental preservation under climate change is intensifying efforts to boost capture, storage and sequestration of carbon. However, as Earth's biological carbon sinks also shrink, remediation has become a key part of the narrative for terrestrial ecosystems. In contrast, blue carbon on polar continental shelves have stronger pathways to sequestration and have increased with climate-forced marine ice losses – becoming the largest known natural negative feedback on climate change. This work explores the size and complex dynamics of blue carbon gains with spatiotemporal changes in sea ice (>100 $MtCyr^{-1}$), ice shelves (40 $MtCyr^{-1}$ = giant iceberg generation) and glacier retreat (under measurement by UK-Chile ICEBERGS project). Estimates suggest that reducing duration of seasonal sea ice is most important. Decreasing sea ice extent drives longer (not necessarily larger biomass) smaller cell-sized phytoplankton blooms, increasing growth of many primary consumers and benthic carbon storage – where sequestration chances are maximal. However, sea ice losses also create positive feedbacks in shallow waters through increased iceberg movement and consequential scouring of benthos. Unlike sea ice, which enhances existing sinks, ice shelf losses generate brand new carbon sinks both where giant icebergs were, and in their wake. These also generate small positive feedbacks from scouring, minimised by repeat scouring at hotspots. Blue carbon change from glacier retreat has been least well quantified, although emerging fjords are small areas which have high storage-sequestration efficiencies. Next steps are wider verification of blue carbon gains, projecting future change, environmental economic benefits and safeguarding these through law.

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Seabed habitats and fauna of the Ross Sea Marine Protected Area: new photographic surveys of the Ross Sea continental slope and Pacific-Antarctic Ridge provide insights into distributions

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To ascertain whether the Ross Sea Marine Protected Area (RSMPA) is fulfilling its primary role - to conserve representative ecological structure and function - the Science and Research and Monitoring Plan for the RSMPA requires improved baseline knowledge about the habitats encompassed by the RSMPA boundaries, assessment of how representative these are of the wider region, and how they might be affected by environmental change and human disturbances. During research voyages in 2018 and 2019 dedicated to informing the Research and Monitoring Plan, we ran seabed photographic transects in previously un-surveyed areas on the northern and eastern continental slopes of the Ross Sea, both inside and outside the RSMPA, and on a ridge feature north of the Ross Sea, 'Long Ridge', which is a focus of the long line fishery for Antarctic toothfish (Dissostichus mawsoni) and is thought to be a key spawning area for this species. Combined with data from earlier surveys, our imagery shows that areas of structurally complex and biologically diverse hydro-coral habitat are strongly associated with the outflows of the Drygalski and Glomar Challenger troughs where they intersect the continental shelf-break, that drag marks from long line anchors are widespread in places on the continental slope, and that benthic communities at sites on Long Ridge appear more similar to those on Admiralty Seamount than to those on the neighbouring Scott Seamounts.

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Responses of Southern Ocean benthic habitats and communities to global environmental changes

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The benthic habitats of the Southern Ocean are hugely variable from ice scoured shallows to some rich, abundant, shelf communities with many endemics dominated by suspension or deposit feeders and their predators. They can be an important store of exported carbon from the overlying pelagic system and habitat for commercial fish species. Monitoring change in remote benthic ecosystems is challenging but with decades of coastal observations adjacent to some research stations, increasing ship-based surveys in regions of environmental change and improved data sharing there is much peer reviewed information to assess the responses of benthic habitats to major drivers of change. In this benthic component of the Marine Ecosystem Assessment for the Southern Ocean (MEASO), we outline the driver pathways of direct and indirect human impacts on the Antarctic benthos and review the observed responses to date as well as projections and predictions for the future. Specifically, we highlight the impacts of increasing ocean temperature, marine-ice loss and resulting changes to food availability, increased iceberg scour, ocean acidification, non-indigenous species and fishing pressure on benthic habitats of Antarctica's shelf. Where possible we indicate the most vulnerable areas or species to these drivers whilst considering the spatially variable, heterogeneous and patchy nature of Southern Ocean benthic environments. The MEASO process involved extensive engagement with stakeholders and policy makers. Here we provide a summary based on their feedback including the current measures in place to protect and manage the Antarctic benthos within CCAMLR as well as proposed work plans and potential outcomes.

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Functional resilience of benthic microbial communities to changing sea-ice dynamics in McMurdo Sound, Antarctica.

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Climate driven changes to sea-ice dynamics in polar marine ecosystems are impacting the timing and magnitude of seasonal primary productivity which directly affects the flux and turnover of organic matter in benthic ecosystems. As part of the New Zealand Antarctic Research Institute's "Resilience of Antarctic Biota and Ecosystems" project, we sought to undertake the first study to investigate how changing sea-ice dynamics may impact benthic microbial communities; the key drivers of carbon and biogeochemical cycling. Using a space-for-time model, two locations were chosen within McMurdo Sound with varying sediment organic carbon loading due to variations in annual sea-ice coverage; New Harbour with historically low productivity and persistent multi-year ice, and Cape Evans with high productivity and first-year ice that breaks out annually. Assessment of microbial community composition and taxonomic diversity (DNA barcoding) confirmed that low-productivity sediment communities were phylogenetically distinct from those at the high-productivity location. In examining the metabolic functional capacity (metagenomics) of these distinct sediment communities, both shared and site-specific energy-yielding metabolic functions were identified enabling this study to define the key signatures of microbial community resilience that maintain ecosystem services. Changes in oceanographic and atmospheric circulation patters are clearly driving fluctuations to sea-ice persistence in McMurdo Sound, of which ecological impacts are currently unknown. By examining the composition, structure and function of surface sediment microbial communities for shared and unique microbial processes within McMurdo Sound, this study provides a unique opportunity to describe how distinct microbial functions and their biogeochemical processes may be altered by climate change.

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Peracarid abundance and composition in the Atlantic sector of the Southern Ocean and Weddell Sea

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Peracarids are one of the most dominant and species-rich groups of the Southern Ocean benthos. The composition of peracarid crustaceans and the influence of environmental factors on their abundance patterns were assessed in the Atlantic sector of the Southern Ocean and in the Weddell Sea. Samplings were performed by means of an epibenthic sledge (EBS) during the expeditions on board of the RRS James Clarke Ross (South Orkney Islands, JR15005; Prince Gustav Channel, JR17003a; Filchner Trough, JR275) and the RV Polarstern (Eastern Antarctic Peninsula, PS118). The sampled areas were characterised by different regimes of ice-cover extent and by a depth range of 403-2021 m.
In total 64,766 peracarids were found and sorted into five different orders (Amphipoda, Cumacea, Isopoda, Mysidacea and Tanaidacea). Amphipods were the most abundant group representing the 32% of the total abundances. The number of individuals decreased with depth, whilst ice-cover extent together with phytoplankton and chlorophyll concentration was positively correlated with the number of peracarids. Our study showed that environmental factors play an important role on peracarid distributional patterns and strongly influenced their abundance.

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Environmental and biological drivers of skeletal mineralogy of marine calcifiers from the Antarctic shelf: insights from the CEAMARC voyage

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The Southern Ocean will be one of the first regions to be affected by ocean acidification (OA) due to low water temperature and higher CO2 solubility, low carbonate saturation levels and weak buffering capacity. Its pH levels have already decreased by 0.1 units and are projected to decline by a further ~0.3 units by 2100. The decline of carbonate ion concentrations can cause calcium carbonate (CaCO3) minerals to become undersaturated. Therefore, biodiverse shelf assemblages of marine calcifiers will be exposed to undersaturated conditions, potentially making them vulnerable to a range of effects such as dissolution of their shells or skeletons. Marine calcifiers depositing more soluble CaCO3 mineral phases (e.g. Mg-calcite) may be more vulnerable and among the first affected. Global warming may also exacerbate the effects of OA in species with Mg-calcite shells and skeletons as Mg content generally increases with seawater temperature. Our understanding of potential OA impacts on marine calcifiers, especially from high latitudes, is limited by the lack of mineralogical data for most species, and limited geographical coverage. This is the first study examining a large dataset of skeletal mineralogy from a broad range of Antarctic marine calcifiers collected over a wide depth range during the Collaborative East Antarctic Marine Census voyage. Here we discuss i) the potential environmental (e.g. depth) and biological (e.g. food availability) factors influencing their skeletal mineralogy, and ii) taxa that may be particularly vulnerable to near-future OA and may make suitable indicators to monitor effects of OA in the Southern Ocean.

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Mapping seafloor biodiversity and carbon pathways on the Antarctic continental shelf

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Antarctic seafloor communities are rich, endemic and often high in biomass, but their distribution is poorly known because biological data away from research stations and a few other hotspots are sparse. Here we detail and present the highlights to date of an ambitious four-year project that aims to map the distribution of seafloor biodiversity, the primary production reaching it and the carbon stored by it, across the entire Antarctic continental shelf. The project consists of several components including; 1) the collation of a large repository of benthic images and the generation of a unique database of consistently annotated data on abundances of benthic, 2) the application of a unique and validated approach to estimate the redistribution of surface primary production to the seafloor, 3) the use of new statistical methods in ecology to match the sparse biological data with environmental data to enable full-coverage maps, and 4) the estimation of the amount of atmospheric carbon stored by animals at the seafloor. The project will explore patterns in and drivers of several aspects of Antarctic seafloor biodiversity including species groups, bioregions and vulnerable marine ecosystem taxa. Maps of the predicted distribution will be invaluable tools underpinning policy, spatial management, conservation, and future science.

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An ensemble modelling approach to mapping functional group diversity at South Georgia – A case study for assessing priority zones for conservation at very large MPAs

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The functional structure of a community can be represented by faunal traits such as mobility, feeding and reproductive strategies. Classification of these traits into functional groups represents a means of simplifying the complexity of biological systems, helping to inform on the provision of ecosystem services and predict community responses and resilience to disturbances. As such, we argue the analysis of functional groups and their diversity is an important consideration in the effective management and conservation of the marine environment.

Using a multi-model, ensemble approach to habitat suitability modelling, we mapped functional group distribution and diversity in respect to management zones at sub-Antarctic South Georgia. This was analysed alongside conventional metrics of conservation management (e.g. vulnerable marine ecosystems). Modelling across large remote polar regions such as South Georgia, at a scale relevant to their management, is challenging due to reliance on presence-only, spatial heterogeneous data. An ensemble approach allowed quantification of variance in modelling performance between response variables and modelling algorithms, providing a measure of confidence for each model.

The spatial distribution of high functional diversity demonstrated the highest likelihood of occurrence on the island's upper continental slope, thus overlapping with the boundary of the managed fisheries zone. As such, we discuss the implications of these results in informing on spatial management of the MPA. Furthermore, we discuss modelling improvements and data validation techniques, such as using fisheries longline camera data, that could aid the use of habitat suitability maps in managing the impact of fishing on Antarctic benthic ecosystems.

A circumpolar database of high-quality biological and environmental data for analysing Antarctic seafloor biodiversity

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The Antarctic seafloor contains unique and diverse species communities. However, because observations are sparse, the distribution of Antarctic seafloor biodiversity is little known, hindering implementing conservation measures, developing policy and predicting responses of Antarctic marine ecosystems to environmental change. In this talk I present two key developments that change the type of questions we can ask and answer regarding Antarctic seafloor biodiversity and its potential future change:
First, we've collated seafloor images from all major Antarctic expeditions dating back to 1985 into a single, circumpolar database containing close to 100,000 images and annotated a representative subset of approximately 2,000 images to morphospecies level. Annotations are reproducible, editable by experts, suitable for training deep-learning models and will become open source.
Second, we've created the first circumpolar maps of estimated food-availability at the seafloor, a critical environmental factor influencing all seafloor animals. In addition to food-availability and other environmental data such as bathymetry, the environmental database contains seafloor current speeds, tidal movements and ocean temperatures at 2km resolution.
I use these two databases in an initial analysis to show the spatial extent of the continental shelf that has similar environmental conditions to where imagery has been sampled from. This analysis also highlights gaps in the coverage and is useful to prioritise future sampling efforts.
The two databases will allow for the first time to estimate distributional patterns of Antarctic seafloor fauna abundances and diversity at the continental scale, estimate their total biomass and secondary production, and characterise ecoregions for conservation and management.

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Krill Observational Moorings for Benthic Investigation (KOMBI)

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An as of yet unknown proportion of the krill population travels to and may reside near the seafloor and so may offer a bridge between the pelagic and benthic realms enabling the transport of carbon and nutrients. Australia plans to construct three sea floor moorings to monitor sea floor habitat use by krill over an entire year. The moorings will be deployed in the Indian Ocean sector around 66°S 63°E from Australia's RV Investigator during the Antarctic krill biomass survey in CCAMLR Division 58.4.2 East from January to March 2021. Each mooring will consist of an upward looking Nortek Signature 100 Echosounder / ADCP secured with a 6 metre tether to a sea floor lander. The lander will include a CTD and an illuminated video system that is capable of recording 5 minutes of video every 5 hours for an entire year. An autonomous passive acoustic instrument for recording marine mammal vocalisations will also be attached to the mooring to further extend the coverage of such instruments currently deployed in the East Antarctic. The moorings will be recovered from the Australian Antarctic Division's RSV Nuyina during the following summer.

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Factors influencing the distribution of organic matter in sediment on the Sabrina Coast slope and rise

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Understanding the processes affecting the composition and distribution of organic matter on the seafloor has important implications for predicting the nature and distribution of seafloor communities on the Antarctic slope. Models of Antarctic margin sedimentation have emphasised the delivery of organic matter to the sea floor from the water column during interglacial periods and organic-poor siliciclastic material from the ice sheet during glacials. Cores from the Sabrina Coast slope show a more complex picture with some interstadia seeing deposition of foraminifer-rich clays rather than biosilicious material. Thus, the nature of organic matter delivered to the sea floor is influenced by the characteristics of the individual glacial or interglacial cycle. The distribution of organic matter on the sea floor is also influenced by depositional environments with most sediment accumulating on ridges separating submarine canyons. Sediment gravity flows and ocean currents then rework material in in some settings. Canyons show signs of bed erosion, but a surprising feature in some canyons is the preservation of biosiliceous mat deposits. These likely accumulated during episodes of specific water column structure after the LGM and are preserved in ponds on canyon floors but not on the intervening ridges. Thus, the availability of organic matter within sea floor deposits varies through time with oceanographic variations and spatially with sea floor processes.

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Antarctic seafloor habitats: Physical processes and sensitivity to change

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Physical processes on the Antarctic shelf and slope create a patchwork of seafloor habitats, contributing to the observed diversity of benthic communities. Many of these key physical drivers are vulnerable to future change, including substrate characteristics, sedimentation and food availability, sea ice regimes, scouring by icebergs and ocean chemistry. Current and future retreat and melt of ice sheets and ice shelves creates a cascade of changes to seafloor environments. Ice shelf collapse initially increases the impact of ice scour on the seafloor and icebergs release ice-rafted debris, potentially including large dropstones, while melt and onshore runoff increases sediment input and affects productivity regimes. Changes to sea ice cover and distribution affect light availability and primary productivity, and may alter the formation of water masses, such as dense shelf waters, that can subsequently cascade downslope, providing an advected food supply to the slope. Changes in ocean chemistry associated with increasing acidification can affect the distribution of calcified benthic organisms. This presentation will assess the known distribution of communities on the shelf and slope of the George V and Sabrina regions to determine which habitats are most vulnerable to change, and how these benthic communities may respond to changes in these key physical drivers. These results can inform management of seafloor environments to minimise additional pressures in sensitive areas and to identify refuge areas that can be prioritised for protection.

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In depth exploration of the biodiversity of asterozoan fauna in Admiralty Bay and Bransfield Strait, Antarctic Peninsula

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Both Asteroidea and Ophiuroidea, together referred as the Asterozoa, are marine invertebrates forming a major part of the benthic ecosystem of the Southern Ocean and are dominating in abundance and biomass. They represent major links within food chains and account for substantial transitions and fluxes of organic matter within this highly productive environment.
However, research on them is complicated due to difficulties in accurately identifying them based on morphological methods alone. The asterozoans are riddled with taxonomic uncertainties and have undergone multiple revisions in individual taxonomic groups throughout time. These uncertainties can have a range of different reasons, including unclear descriptions, in which morphologically relevant structures have appeared under different names depending on the author, the difficulty in identifying juvenile and pre-metamorphosed larval stages, adaptive plasticity during different developmental stages, and the presence of cryptic and sibling species. To solve this confusion, we aim at complementing these traditional methods with molecular approaches for species delimitations (i.e. amplification and sequencing of the mitochondrial cytochrome oxidase (COI) barcoding gene), to investigate in depth the diversity of Asterozoa in Admiralty Bay and along the Bransfield Strait. In this study, molecular and morphological approaches will be jointly applied to samples collected during the ANTARXXVII campaign from December 2019 to January 2020 through diving and sampling with a Van Veen grab. By integrating both approaches, our study will provide a more accurate taxonomy and a better understanding of the pattern of biodiversity, generating a baseline for further studies on biodiversity, ecology and conservation.

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Small but important: Environmental drivers decisive for community composition are different when meiofauna is included in benthic surveys of regions with varying sea-ice regimes

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Benthic organisms depend on food input from the water column. Separate studies on Southern Ocean macro- and meiofauna showed that sea ice - among other environmental factors - plays a major role in structuring communities. It is, however, unknown how environmental changes may affect the benthos altogether. We investigated the relation among environmental factors, food availability at the sea floor, and meio- plus macrofauna community compositions. Samples were taken during two expeditions with RV Polarstern, PS 81 and PS 96: Four investigated areas represent three different sea-ice conditions in the Southern Ocean: I. South-Eastern Weddell Sea (lasting ice cover), II. Drake Passage (least ice cover), III. Bransfield Strait and the North-Western Weddell Sea (variable ice cover). Faunal analysis were carried out on sediment cores. Environmental factors were temperature, salinity, and chlorophyll a for the water column and grain size, TOC, TN, and pigment content for the sediment. Preliminary results indicate that macrofauna communities in regions with "lasting ice cover" are more similar to communities in regions with "least ice cover", than to those from regions with "variable ice cover". Against our expectations food input (Chla content, TOC) has only a strong impact on macrofauna community composition. In contrast, ice cover and TOC are the structuring factors for meiofauna and meio-plus-macrofauna communities. Based on these results the previously under estimated meiofauna plays a major role for the community structure at the seafloor. These findings show that a complete assessment of the influence of environmental changes should encompass all major faunal components.

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Do habitat-formers facilitate deep sea benthic communities?

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Positive interactions between species often shape the composition of communities, however, the importance of these interactions can fluctuate spatially and with different environmental conditions. There are multiple environmental factors that control the distribution of deep-sea benthic communities, but it is unclear whether species which provide complex physical structure such as bryozoans and sponges etc. have additional effects on the distribution, composition and productivity of the associated communities. We are in the process of compiling and annotating the most comprehensive set of deep-sea benthic images around the Antarctic continent, which in combination with the corresponding environmental data including modelled food availability, will form an invaluable database for understanding and predicting patterns in benthic biodiversity. Using this database, we will present findings which examine the relationship between structural habitat-formers and mobile species across different habitats types and different levels of food availability. We will discuss the significance of facilitation in driving species composition and secondary productivity and the role of environmental conditions in mediating the association between habitat-formers and mobile species.

1585

The coastal marine benthic ecosystem of the Vestfold Hills, East Antarctica: a hotspot of biodiversity and heterogeneity.

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The Vestfold Hills in East Antarctica (location of Australia's Davis station) is an area of permanently ice free coastal habitat, consisting of rocky peninsulas, valleys and islands with marine systems that include shallow embayments, deep fjords, sheltered waters in-between islands and the mainland, and open coast. We present on overview of this marine ecosystem, based on recent and past research dating back to 1977, including a large scale environmental survey in 2010 and hydroacoustic mapping of benthic habitats. Surveys of the fjords are limited and their bathymetry and geomorphology are poorly known, despite their large extent in this biologically important area. The marine benthic ecosystem of this area appears to be highly heterogeneous, with a wide range of habitats, within which there are a wide range of benthic communities with very high levels of heterogeneity. Several distinct communities have been observed which may be classifiable into discrete biotopes. Biotope examples include the invertebrate dominated communities found under sea-ice such as the polychaete reefs in Ellis Fjord, and mixed assemblages of filter feeding invertebrates; to communities dominated by varying proportions of red and brown macroalgae. These patterns appear to be influenced by a combination of physical and biological drivers including sea ice, physical disturbance (or lack of), high levels of pelagic primary production, and reproductive and dispersal processes. Some of these biotopes and communities may be quite resistant or resilient to environmental change, however, some biotopes may be highly vulnerable and at risk.

Biogeochemistry of surface sediments in an Antarctic nearshore area affected by recent glacier retreat: Collins Harbor, King George Island

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Biochemical composition of sedimentary organic matter, grain size, major and trace elements were analysed at 10 sampling stations in Collins Harbor, Maxwell Bay, to evaluate sources of particulate material in the seafloor. Surface sediment samples were taken with a grab, during the ANTAR XXV expedition in January 2018, onboard the BAP Carrasco from the Peruvian Navy. Coarse sediment fractions decreased, while mud content increased towards the centre of the bay. Positive correlation between mud and biopolymeric carbon (BPC) indicated depositional conditions and organic material accumulation in the deepest central area. Proteins (PRT) predominated over other biochemical classes contributing to labile organic carbon, followed by lipids (LIP) and carbohydrates (CHO). PRT positive correlation with Ba, Ca and Al indicated that labile organic carbon inputs derived from marine primary production. Whereas, PRT positive correlation with K and Ti suggested also the influence of terrestrial supply through Collins Glacier meltwater runoff. Mn/Ti, Mn/Al and Fe/Al ratios decreased towards the centre of the bay, while the Ba/Al ratio showed the opposite trend. This distributional pattern suggested the diminish of glacial and terrigenous sedimentation towards the deepest central area of the bay, with the increment of marine particulate material deposition and accumulation. Igeo values between 0 and 1 showed unpolluted conditions in Collins Harbor for Cr, Ni, Cu, Zn, As and Pb, which concentrations may reflect background values for this area. Natural inputs from weathering, glacial runoff and marine primary production are main sources of particulate material in Collins Harbor, with none detected anthropogenic contributions.

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Using Bayesian network inference to infer likely changes in benthic community composition communities from the marine protected area of South Orkney Islands Southern Shelf

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The benthic communities around the South Orkney Islands have exceptionally high biodiversity, representing one fifth of the species found in the Southern Ocean. It is not understood how community dynamics are likely to change in the advent of anthropogenic change such as the removal of Porifera due to potential long-line fishing. To investigate likely consequences of Porifera removal on community dynamics we use Bayesian network inference to reconstruct a fine-scale (~1m) and large-scale (~1km) ecological networks from five areas around the South Orkney Islands. These networks are used to identify the key drivers on community composition and then to infer how taxa abundances change when Porifera are removed from the system. We found that substrate is the most connected node for the small-scale network while in the large-scale network Porifera had the most significant dependencies on other taxa. When Porifera were removed from the network, the abundances of all taxa were reduced significantly, apart from Arthropods who showed a small increase in abundance. The taxa such as Bryozoans, Molluscs and Echinoderms that had direct dependencies on Porifera showed the greatest reduction, while taxa such as Cnidaria, that had intermediate dependencies showed a smaller reduction. The negative feedback between Arthropods and Euryalida counteracted the reduction of Porifera, so were not negatively impacted. This study is the first time the cascade effects of removing key ecosystem structuring organisms has been used to statistically analyses data from a Southern Hemisphere MPA, and demonstrates the importance of considering the community dynamics when assessing resilience.

1502

Patterns in the distribution of seafloor biodiversity on the North Antarctic Peninsula

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Antarctic seafloor communities are unique and highly diverse. Changing environmental conditions, in particular along the rapidly warming Antarctic Peninsula, are expected to cause shifts in the composition, function and distribution of these communities. Understanding current distributional patterns of seafloor biodiversity can serve as a baseline from which to monitor future shifts in faunistic patterns. However, the complex interplay between various environmental factors peculiar to high-latitude systems often makes it difficult to isolate the main predictors of seafloor biodiversity – particularly at larger scales – and can confound attempts to accurately predict the distribution of benthic assemblages. We use statistical models based on generalised linear models to analyse distributional patterns of 80 morphospecies identified from seafloor imagery alongside various environmental variables previously reported to correlate with benthic community structure. We identify key broad-scale environmental drivers of faunal distributions on the continental shelf of the North Antarctic Peninsula and generate predictive maps of seafloor biodiversity. Distributional maps of seafloor biodiversity are valuable for gauging the potential locations of Vulnerable Marine Ecosystems across areas of shelf for which we lack direct biological observations, and can therefore be used to inform marine spatial management and conservation strategies.

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SESSION 34

PROGRESSING ENVIRONMENTAL PROTECTION OF ANTARCTICA AND THE SOUTHERN OCEAN THROUGH SCIENCE

Aleks Terauds, Mecha Santos
Daniela Liggett, Luis Pertierra

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Assessment of plant biodiversity in the Vestfold Hills, East Antarctica

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The Vestfold Hills is a 400 km2 ice-free oasis on the Ingrid Christenson coast, East Antarctica. The distribution of plant species across the Vestfold Hills was investigated through an extensive stratified random sampling design. Ten habitat types were identified through fuzzy c-mean classification of spatial data from high resolution Digital Elevation Models. Random points were assigned to these areas and 300 sites were visited during the 2019/20 austral summer. Each site was assessed for chasmoendoliths (algae or cyanobacteria growing in rock cracks), sublithic (under rock) flora and surface flora. Patterns identified in the 1980's of rich surface flora towards the ice plateau and away from salt and wind- blown sediment were confirmed. Most sites across the Vestfold Hills had sublithic and chasmoendolithic algae and cyanobacteria dominant plant assemblages under quartz rocks. Surface plant assemblages included moss and lichen beds in drainage valleys and lithic lichen assemblages on primarily protected south or west rock faces.

1509

A scientific work plan to develop effective ecosystem-based management for the Antarctic krill fishery

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Antarctic krill (Euphausia superba), thought to have the largest biomass of any animal species on Earth, are the center of Southern Ocean food webs. Krill are also at the center of management for the Southern Ocean: The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), originally known as the "krill convention," came into force in 1982 in response to the growth of the Antarctic krill fishery. With conservation as the core objective of the Convention, CCAMLR has the mandate and opportunity through the krill fishery to lead the world in developing precautionary ecosystem-based fisheries management.

CCAMLR has been working toward developing a new ecosystem-based fishery management system, grounded in robust science. A new scheme is urgently necessary since the current system allows concentrated fishing which is negatively impacting krill predators. Meanwhile, both krill and krill-dependent predators are experiencing the effects of one of the most rapidly warming climate systems on earth. In 2019, CCAMLR adopted a scientific work plan that will form the basis for the revision of the krill management measure that is scheduled for 2021.

Here we present an update on the status of Antarctic krill fishery management. We also outline the three key elements of the new krill science work plan - a biomass estimate and stock assessment to ensure a healthy krill population, and an ecosystem risk assessment that will allow CCAMLR to set catch limits that minimize the impact of the fishery on krill predators by reducing fishing in their key foraging areas.

945

Who’s going where? Making the best use of logistical information to get more science done

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The Southern Ocean is critically under-observed, which increases the uncertainty in global climate models and other scientific studies.

While individual nations have competitive systems to allocate space and time on their research vessels and aircraft, it is difficult for researchers to find advance information on where vessels outside their national programs are going. Between National Antarctic Programs, tourist vessels, and fishing programs, there are hundreds of vessels in the Southern Ocean each year. Many of these have the potential to deploy observing equipment or to carry scientists but it is difficult for scientists to take advantage of these opportunities because of the opaqueness of voyage planning information.

The Southern Ocean Observing System is tasked with knitting together a sustainable, comprehensive system of ocean observations. To do this, the community needs to make the best possible use of existing logistical resources.

DueSouth (https://data.aad.gov.au/duesouth/) - a Database of Upcoming Expeditions to the Southern Ocean - is designed to support this. DueSouth gets regular feeds of information about vehicle movements from National Antarctic Programs, CCAMLR fisheries vessels, and the Go-Ship program, courtesy of JCOMMOPS. We are working on getting tourist vessel information into the database as well. Additionally, we invite members of the Southern Ocean community to upload information about voyages in their programs.

We will share the lessons of our progress in developing DueSouth and invite contributors to help us create a richly populated tool that helps scientists make the best possible use of the resources we already have.

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Managing Marine Protected Areas in Remote Areas: The Case of the Subantarctic Heard and McDonald Islands

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Large marine protected areas (MPAs) are increasingly being established to contribute to global conservation targets but present an immense challenge for managers as they seek to govern human interactions with the environment over vast geographical expanses. These challenges are further compounded by the remote location of some MPAs, which magnify the costs of management activities. The Australian subantarctic Heard and McDonald Islands (HIMI) Marine Reserve is among the world's most remote MPAs and is relatively large (~71,000 km2). We performed an in-depth case study of the HIMI Marine Reserve using the social-ecological systems meta-analysis database (SESMAD) to characterize the structure of conservation governance and outcomes. The Marine Reserve has generally been successful in supporting a sustainable fishery for Patagonian toothfish while also addressing threats to biodiversity. The remote and isolated nature of the Marine Reserve was critical to its success, but also benefited greatly from collaborations between managers and the fishing industry. Commercial fishers keep watch over the Reserve while fishing, report any observations of illegal fishing, and have at times been asked to verify remote observation of potential illegal fishing vessels. The industry also undertakes annual ecological surveys in the MPA, allowing managers to track environmental trends. The fishing industry itself highlights the importance of industry participation in conservation planning, strengthened by secure access to resources via statutory fishing rights, which provide critical incentives to invest in conservation. We therefore reflect on the potential application of this case to other remote large MPAs, highlighting potential directions for future research.

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Conservation Planning for Antarctic Research Stations

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The small ice-free areas of Antarctica are essential locations for biodiversity and science, but are also subject to pronounced and expanding human impacts from research station activity. Awareness of the need to conserve these natural values by station operators does exist, but management of impacts typically occurs on a reactive basis. While there has been growing momentum to expand Antarctic Specially Protected Areas to ensure conservation of such values, there is also a need for wider management of impacts to be commensurate with the continent's designation as a natural reserve. By using a case study of Australia's Casey Station, this project found significant natural values still persist within close proximity of long-term station infrastructure, but encroachment by the footprint of activity has been an ongoing pressure. Here strategic planning to better conserve such values provides a direct opportunity to enhance protection of the Antarctic environment. This paper introduces a systematic conservation planning approach, tailored to Antarctic research stations, to aid operators to improve the conservation of values surrounding their activities. Use of this approach provides an opportunity to balance the need for scientific access to the continent with international obligations to protect the environment.

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Benthic biodiversity associated with shallow rocky reefs in Antarctica.

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Marine benthic ecosystems are experiencing a pervasive change in biodiversity mostly due by global change, especially in polar ecosystems. In Antarctica, one the most conspicuous environments supporting a high biodiversity are rocky reefs, characterized by the presence of algae-dominated benthic communities from 5 to 25 m depth forming dense algal forest (Desmarestia antarctica), sheltering under the algal canopy there is a diverse biota composed of red algae, sponges, tunicates, hydrozoas, anemones, echinoderms, soft corals and other filter-feeding organisms. At the same time each of these organisms can act as a micro habitat for smaller species such as amphipods, pycnogonids, bivalves, brachiopods, worms, etc. The aim of the present study is to provide the baseline information describing the biodiversity, abundance, bathymetric distribution and physical parameters of shallow-water rocky reefs by classifying marine biogenic habitat in Fildes Peninsula, King George Island, Antarctica. Benthic assemblages between 5 and 15 m depth were sampled by SCUBA diving from 10 different rocky reefs. A total of 131 species of macro-organisms were found, belonging to 16 filo. These results show higher values of species richness than previously reported around Antarctic Peninsula. Fondap IDEAL 150003.

1456

The biggest moss transplant in Antarctica the case of Brazilian Station Comandante Ferraz

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During the reconstruction of the new Brazilian Station Comandante Ferraz, the new buildings were to be constructed partially over a moss carpet. It was decided by the Brazilian Navy, the Brazilian Environmental Agency (IBAMA) and the Chinese company CEIEC to move the carpet to a new location in order to protect it. Initially the area was measured and a new site as similar as possible to the original was chosen, for that was taken into consideration the size, slope, soil and humidity. Moss carpets where divided in manageable sizes (about 0,2 m^2) and with the help of shovels, knife or manually, were removed. Mosses were disposed on trays or plastic boxes and immediately relocated. The patches contained also 5 cm depth of soil to keep the moisture, nutrients and associated fungi necessary. Transplants were performed during the summer of 2016/2017. The area was monitored the following summers to check if the transplanted patches were thriving. The total area is 650m2, making it the biggest moss transplant ever made in Antarctica and maybe in the planet. Transplanted carpets contained Sanionia uncinata, Schistidium antarctici, Polytrichastrum alpinum and the flowering plant Deschampsia Antarctica. Moss carpets have aesthetical value but also retain water and harbors little known communities of Springtails, Mites, Tardigrades, Nematoda, algae, Chromista, Protista, countless fungi and bacteria and certainly a handful of unknown organism as well. Some of them only survives due to shelter, water and temperature control provided. It is important to stress that a whole community is preserved hence.

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Phylogenetic diversity as an index for conservation planning in the Southern Ocean

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A huge barcoding effort has been ongoing since the last IPY (2007–2008) and resulted in a wealth of taxonomic findings. New species as well as yet unrecognised variants have been discovered and described. In parallel, conservation planning in Antarctica has strengthened with the enforcement of the Heard Island and McDonald Islands (HIMI) Marine Reserve, extension of the National Marine Reserve in the French exclusive economic zone (EEZ) at Kerguelen and Crozet, the implementation of the South Orkney Islands southern shelf and the Ross Sea region marine protected areas (MPAs), and East Antarctica, Weddell Sea phase 1 & 2, Domain I and sub-Antarctic MPA projects. Conservation planning has also acquired refined methods that can now include evolutionary indices such as phylogenetic diversity (PD) to take into account the history of taxa. This index is highly dependent on the number of species included in the analysis and also highly dependent on our knowledge of their inter-relationships.
Here we use multiple taxa for which a phylogeny is available (Echinodermata, Teleostei, Arthropoda, etc) to estimate PD at various geographical scales (habitat, ecoregion, statistical subarea) . We used the unifying approach of Chao et al. based on Hill numbers to derive rarefaction (interpolation) and extrapolation (prediction) curves to make fair comparisons of Faith's PD among several assemblages based on heterogeneous sampling effort in each assemblage.
Results show that contrasting PD indices may be derived from different areas around Antarctica. However, confidence limits may overlap as a result of knowledge gaps.

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Proposed Antarctic Specially Protected Area Argentine Islands – Kyiv Peninsula region

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The role of the Antarctic Specially Protected Areas (ASPA) in biodiversity protection is at risk due to its fragmentation and lack of representativeness. Expanding the protected area networks alone isn't enough. Ensuring effective ASPA functioning also requires continuous coverage, ongoing monitoring by the proponents and a systematic conservation planning (SCP). Here we propose establishing a new ASPA on the Argentine Islands, totaling approximately 35 km2.
The islands have diverse geological formations: the spectacular outcrops of the Antarctic Peninsula Volcanic Group succession, fossiliferous siliceous rocks, ancient gabbroids, and red jasper-like vein mineralization in the volcanites on the Yalour Islands. Numerous seasonal lakes and ephemeral springs occur here. The moss and lichen flora of Argentine Islands is very rich; some species show disjunct distribution patterns, which also emphasize the importance of creating large and continuous ASPA. The moss banks of the area are particularly valuable in the context of long-term climate monitoring. Both Antarctic vascular plants are abundantly growing here as well. A southern boundary of Pygoscelis antarctica and P. papua runs through the proposed ASPA, which provides unique observation possibilities.
Our approach is based on the SCP key steps; it enables the effective protection of local biodiversity, which is under pressure because of tourist and climate factors. To understand and monitor biological responses to climate change, numerous experimental plots were established as well, and equipment was constructed on the Argentine Islands area.

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The Development of the Visitor Site Guidelines for the Argentine Islands, Antarctic Peninsula

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The recent substantial increase in cruise tourism in Antarctica has placed a significant burden on its ecosystem. Anchoring, landing, walking and camping endanger Antarctic fragile vegetation, sea life, birds and hauling-out mammals. Although the Protocol on Environmental Protection to the Antarctic Treaty (1991) had incorporated code of conduct for Antarctic visitors, additional Recommendation XXVIII-1 Guidance for Visitors was adopted in 1994, aiming to enable visitors to comply with the Protocol restrictions. However, it became clear that some sites required additional instructions and hence Visitor Site Guidelines have been adopted since 2005. In this research, we present the Visitor Site Guidelines for central Argentine Islands (Galindez, Skua, Winter, and Grotto), that aim to ensure the safety and security of both local biota and visitors. This region is extremely rich in biodiversity: penguins, seals, petrels, terns, moss banks, dozens of lichens species, relatively abundant vascular plants. We believe that tourism activities, organized according to the proposed plan, will have minimum impact on these organisms. Firstly, we open Vernadsky station and historic Wordie House for tourists. Visitors can enjoy wildlife and landscapes on two open routes: to the Woozle Hill on Galindez Island and to the glacier on Winter Island. The rest area will be closed for tourist security. Secondly, we distinguish between closed waters – Skua Creek, Penguin Point sea areas, dangerous Cornice Channel, no-anchoring zone in Meek Channel and Stella Creek – and those for yachts anchorage and landing. Finally, maximum total number of visitors is limited for ensuring environmental protection.

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Biosecurity at Antarctica New Zealand: Past, Present, Future.

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Addressing non-native species (NNS) introductions in Antarctica is one of the Committee for Environmental Protection's (CEP) priority issues. Antarctica New Zealand has a NNS surveillance programme dating back to the 2005/2006 Antarctic season, which includes measures for the prevention, monitoring and response of NNS incursions to Scott Base, Ross Island. These measures align with the guidelines outlined in the 'CEP Non-Native Species Manual' (Resolution 6 (2011)) and the 'Checklists for supply chain managers' developed by the Scientific Committee on Antarctic Research (SCAR) and the Council of Managers of National Antarctic Programs (COMNAP). The two major risk pathways for the introduction of NNS as a result of New Zealand's Antarctic programme are between New Zealand and Antarctica (inter-continental introductions), and between regions within Antarctica (intra-continental introductions). Climate change and increases in human activities are predicted to exacerbate these risks.

The focus of the surveillance programme to date has been on the prevention and mitigation of inter-continental introductions of NNS and we now have over a decade's worth of data on the detection of NNS incursions at Scott Base. The movement of food, and cargo via aircraft, are the most common inter-continental pathways for introduction. Less is known about the risk of the intra-continental transfer of NNS across distinct Antarctic Biogeographic Regions but it is a risk we are exploring preventative measures for. With the upcoming Scott Base Redevelopment, Antarctica New Zealand has identified options to further reduce the risks of NNS introductions, thus expanding the scope of the biosecurity surveillance programme.

1351

Research and monitoring within marine protected areas: benefits for conservation effectiveness and response to change

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Marine protected areas (MPAs) are one of a suite of management tools that can be used to conserve biodiversity and habitats in response to the current and potential impacts of human activities such as fishing. Reducing such anthropogenic pressures may also go some way towards mitigating the broader impacts of climate change, but MPAs cannot themselves limit processes such as ocean warming or changing sea ice conditions, which are driven at regional or global scales. However, a strategically developed system of MPAs can be a valuable means by which to facilitate research that improves understanding of changing ecosystems, and provides the information necessary for protection and management measures to be effectively adapted in response to such changes. MPAs are therefore important as a scientific resource as well as a conservation mechanism.

We examine how the MPAs established in the Southern Ocean to date have approached the development of Research and Monitoring Plans (RMPs), and suggest practical steps to ensure that such plans are effective in generating outputs that can inform decision-making and support management into the future. Integrating considerations of climate change into both the design and review of MPAs, as well as their associated research and monitoring activities, should allow for a more responsive, adaptive and flexible system of spatial protection to be implemented. A collaborative approach to achieving RMP objectives will be critical to achieving this in practice.

1538

Metagenomic analysis of detectable population shifts in the bodily microflora of a single visitor over the course of a 22-day sailing voyage to Graham Land from Ushuaia

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With an emerging and ever-expanding human presence in Antarctica, we must likewise examine the movement of human-associated microbial flora that we carry to and from the continent.

Over the course of a 22-day voyage on the Bark Europa, voyage crew member and expedition scientist (microbiologist) Dr. J.J. Hastings collected swabs over eight sites on her body to follow the manner in which her microbiome changed over the course of her voyage. The initial swabs were taken as the ship sailed from Ushaia, then again midway through the voyage after reaching Graham Land, and finally after completing the return voyage across the Drake as the vessel entered the Beagle Channel. Through a metagenomic analysis of the 24 samples collected over the course of the voyage, Dr. Hastings was able to identify which species she carried to the Continent on her body, what then began to populate her body as she came into contact with the indigenous microflora of the South Shetland Islands and Graham Land, as well as what species of microflora remained with her on the journey back to South America.

Dr. Hastings has employed this methodology of longitudinal metagenomic analysis over the course of other expeditions she has led, including space simulation missions in confinement. She hopes to repeat this study with future expeditionary missions to Antarctica to provide better guidance for monitoring and providing effective countermeasures for environmental protection of Antarctica.

1181

Substantial increase of ship and air traffic on Fildes Peninsula, King George Island, the main logistic hub for the Antarctic Peninsula

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The Fildes Peninsula, King George Island, South Shetland Islands, hosts six permanent stations and a gravel runway. Due to the vicinity to South America and the good accessibility for aircrafts and ships the region represents the main logistic hub for the South Shetland Islands and the Antarctic Peninsula. Data on ship and air traffic on Fildes Peninsula and the adjacent Maxwell Bay have been collected during the austral summer since 2003/04 and revealed a substantial growth of ship and air traffic. The construction of an aircraft parking platform in 2004/05 allowed a considerably higher throughput of aircrafts. Furthermore, so-called air-cruise programs, where cruise passenger arrive and leave by air, were initiated in 2003/04 and have increased significantly since then. Consequently, a strong increase of ship and air traffic was observed on the Fildes Peninsula and in the Maxwell Bay during the study period. This observation is connected with a general increase of a multitude of human activities including scientific research, station operations, transport logistics and tourism in the area of the South Shetland Islands and the Antarctic Peninsulas. The increasing human pressure by increasing air and ship activities have the potential to negatively affect the local ecosystem, although some evidence of habituation effects in seabirds could be found.

1017

Bioremediation of fuel contaminants across Antarctica. Key findings from field based studies at Argentinian and Australian stations

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In response to the Madrid Protocol (1991), joint signatory nations, Australia and Argentina, have actively researched and implemented strategies for managing and remediating environmental impacts from human activities in Antarctica. Both nations have ongoing research programs into the effects of contaminants on the Antarctic environment, including the application of bioremediation techniques for hydrocarbon-contaminated soils.

Assessing human health and environmental risks and implementing effective bioremediation strategies for hydrocarbon fuels vary depending on a range of contaminant and site-specific factors. The chemical composition of the fuel and it's amenability to biodegradation as well as physicochemical and biological characteristics of Antarctic soils influence the assessment of risk and the selection of optimum bioremediation strategies.

Through examination of field-scale case studies, we present jointly on the similarities and differences in bioremediation of hydrocarbon contaminated soil in Antarctica, including fuel type and composition (fuels used by Australia and Argentina), environmental conditions (particularly differences between Carlini Station and Casey Station, at opposite sides of Antarctica), soil types, microbial responses, nutrient amendment, and measurement and assessment techniques.

Our research demonstrates the Antarctic-wide benefits of international collaboration through development of effective remediation strategies for Antarctica. These findings directly inform the guide for best practice environmental assessment and remediation in Antarctica, the Antarctic Clean-up Manual, developed by the Committee for Environmental Protection to provide scientifically proven guidance that can be applied to the clean-up of a range of impacted sites in Antarctica.

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Current state of Antarctic biodiversity monitoring

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Long term monitoring is considered to be an essential component of ecological research, allowing key scientific questions for species and communities to be answered. In a time of rapid global changes and ecosystem modification this monitoring becomes increasingly important. Antarctica is known for its unique flora and fauna, however, the current rate of change being experienced across the continent may place many of these species under threat. Therefore, knowing how these organisms are responding to environmental changes is vital in understanding community resilience and resistance and predicting regime shifts, in addition to providing essential information for management and policy development. This review investigates the limitations and gaps in existing long term biodiversity monitoring of Antarctic near-shore and terrestrial zones. Here, we focus on studies of three or more years of non-consecutive monitoring. As a whole, biodiversity monitoring in Antarctica was found to be limited, especially those spanning time scales of ten years or more. As previously highlighted by both Antarctic and global findings alike, there is a stark bias towards monitoring charismatic species, such as penguins and mammals; with more than 75 percent of published monitoring studies being focussed on charismatic species. The varied accessibility across the continent is evident in the scarce spread of monitoring programs. Additionally, inconsistencies in methods limits the capacity for comprehensive comparisons between studies. This review demonstrates the many organisms and communities which have remained under studied in Antarctica, as well as emphasises the need for harmonised protocols and data sharing.

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Using ecotoxicology to inform site specific environmental risk assessment of seepages from fuel spill sites on land into nearshore marine environments at subantarctic Macquarie Island.

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The Australian Antarctic Division has been remediating fuel contaminated sites at Macquarie Island since 2003 to mitigate environmental risk. Alongside this remediation program, a comprehensive environmental risk assessment (ERA) of potential impact of fuels to terrestrial microinvertebrate, plant and microbial communities was completed. As a final phase in this ERA, we determined the residual risk of offsite migration of contamination into nearshore marine environments. Direct toxicity assessments were conducted on seven composite test solutions prepared from field groundwaters and coastal seepages, adjusted to ambient seawater salinity. Eleven native marine invertebrates (including gastropods, bivalves, flatworms, amphipods, copepods, isopods) were exposed for up to 21d, with survival and behavioural observations through time. Lethal time estimates (LT10, LT50) were determined to rank the relative toxicity of test solutions. Sensitivity was time dependent (LT10s = 4-15d) and variable between species. Most species showed no response in the first 5 days, and three species showed no response to any test solution. Overall, no consistent patterns in relative toxicity of test solutions were identified, nor in responses based on hydrocarbon composition of test solutions. While toxicity was observed in some species, this was only under worst case conditions that would rarely occur naturally; undiluted continuous extended exposure without flushing. Results of these toxicity assessments, considered in the context of natural dynamics on-site; including low seep discharge rates, high dilution potential, and highly energetic receiving environment, provide robust evidence that residual contamination at remediated sites at Macquarie Island present a low overall risk to adjacent marine communities.

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Risk Assessment and Remediation of contaminants in Antarctica:
How clean is clean enough?

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The Antarctic and subantarctic are generally considered pristine, yet contamination from local and global sources regularly occurs. Contaminated sites from past and present human activities are currently being remediated by Australia, including fuel spills and former waste disposal sites. But when should these sites be considered clean? Ecotoxicological assessments and toxicity tests that determine effects of contaminants on biota are used worldwide as the basis for derivation of Environmental Quality Guidelines, and as lines of evidence in Environmental Risk Assessments. Standardised toxicity tests and Environmental Guidelines are available for temperate and tropical regions, but are not yet developed for Antarctica. Due to the unique properties of Antarctic environments and biota, these guidelines must be based on the response of a range of native Antarctic species. Over the past 15 years, the Australian Antarctic Program has developed a suite of traditional and novel ecotoxicological approaches to determine biological responses and the potential risk of contaminants to terrestrial soils and marine waters in Antarctica. Here we summarise progress to date and the process by which concentration-response curves from toxicity tests are used to derive scientifically robust Environmental Guidelines using Species Sensitivity Distribution models. These models predict concentrations that are protective to a certain proportion of the native community, which can be used as Remediation and Clean-up Targets. This work informs environmental decision making in the AAP, and will be incorporated into the Committee for Environmental Protection (CEP) Clean-up manual, and available for use by other Antarctic Treaty states more broadly.

1648

Antarctic krill fishery effects over penguin breeding populations under adverse climate conditions: implications for the management of fishing practices

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Fast climate changes in the western Antarctic Peninsula (WAP) are reducing krill density, which along with increased fishing activities in recent decades, may have had synergistic effects on penguin populations. We tested that assumption by crossing data on fishing activities and Southern Annular Mode (SAM) with all penguin population data available between 1980 and 2018 for the whole western Antarctic Peninsula, including areas of high and none fishing pressure. Increases in fishing catch within a 30km radius of penguin colonies during the non-breeding period were likely to result in impacts on both chinstrap (Pygoscelis antarcticus) and gentoo (P. papua) populations. Catches and climate change together elevated the probability of negative population growth rates: very high fishing catch under low values of the SAM implied a decreased growth rate. The current management of krill fishery in the Southern Ocean takes into account an arbitrary and fixed catch limit that does not reflect the natural variability of the krill population, therefore affecting penguin populations when the environmental conditions were not favourable. Since Krill flux and recruitment is still not understood, precaution should be applied on management of krill fisheries. Years of warm winter with low sea ice cover should be considered unfavourable and catches should be limited to the lower availability of Krill to top-predators.

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Systematic conservation planning for the Antarctic Peninsula

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The Antarctic Peninsula is one of the most rapidly changing places in the Southern Hemisphere. Home to much of the continent's biodiversity, it is essential that we determine how to best conserve the region's unique values as environmental change becomes more pronounced and as human activity grows. Improving the management of human activity in the region is a key priority for the International Association of Antarctica Tour Operators (IAATO), the Committee for Environmental Protection and the Antarctic Treaty Parties. An integrated approach is required to maintain multiple intrinsic values and stakeholder needs, particularly where human activity is highly concentrated. SCAR and IAATO have partnered in a collaborative project to develop an integrative, evidence-based approach to site management, incorporating science and tourism activities, and all known biodiversity features (such as breeding seabird colonies, vegetation, and invertebrates). Systematic Conservation Planning (SCP) is a conservation science approach employed to aid decision-makers in managing whole landscapes involving multiple stakeholders and multiple objectives. Here we present early results from this project. We highlight several scenarios that prioritise different aspects of site prioritisation, such as biodiversity connectivity, and identify sites important for biodiversity, science and tourism.

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Capturing Legacies of Terrestrial Biology Research for the Future

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Over fifty years of international research has shown that the Ross Sea Region (RSR) contains rich and iconic terrestrial flora and fauna that exhibit complex biogeographic patterns. The distribution and activity of these endemic biological communities are overwhelmingly determined by the availability of liquid water; however, localised warming may significantly change the hydrological patterns in terrestrial Antarctica, leading to non-linear and heterogeneous changes in these unique biotas.

A systematic and comprehensive understanding of taxa distribution and their associated biological and ecological processes is essential to understanding and projecting warming-induced changes in RSR terrestrial biology. As part of New Zealand's Antarctic Science Platform, we will synthesise fifty years of RSR terrestrial biology research outputs in various forms (estimated to be more than 20,000 journal articles and books as well as digital databases) using modern heuristic informatic technologies (e.g., natural language processing, geoparsing, and data mining) and high-performance computing. We will retrieve and organise knowledge embedded within these data sources, many of which were produced before the availability of GPS for field biologists and thus require sophisticated and novel applications of geographic information retrieval techniques.

The compiled data products require review and validation, and we will engage international researchers through a future workshop (tentatively scheduled for 2022) to ensure a balanced representation of the collective knowledge on RSR terrestrial biogeography, which will serve as the framework that enables evidence-based bioregionalisation of the RSR. Here we outline our plans for this ambitious undertaking and invite international researchers across disciplines to join this effort.

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Antarctic wilderness in decline after 200 years of human activity

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Recent assessments of Earth's dwindling wilderness have emphasised Antarctica as a crucial wilderness in need of protection. Yet human impacts on the continent are widespread, the extent of its wilderness unquantified, and the importance thereof for biodiversity conservation unknown. We have assembled a comprehensive record of human activity (2.7 million records, spanning 200 years) and used it to quantify the extent of Antarctica's wilderness, and its representation of biodiversity. In this presentation, we show that 99.6% of the continent's area can still be considered wilderness, but that this area captures few biodiversity features. Pristine areas, free from human interference, cover a much smaller area (< 32% of Antarctica), and are declining as human activity escalates. Urgent expansion of Antarctica's network of specially protected areas can both reverse this trend and secure the continent's biodiversity.

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Hotspots for marine invasive species around coastal Antarctica identified using a network-based risk index

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Previous estimates suggest approximately 180 vessels on 500+ voyages visit Antarctic waters annually [1], each potentially transporting new species to the region. On top of that, rapid environmental change in the Antarctic region is likely allowing new species to establish that were previously excluded by physiological barriers, but the risk they represent is poorly understood. Determining likely locations for anthropogenic introductions and the origins of newly arrived species has significant management implications, including eradication vs protection and where to monitor or implement biosecurity actions.

We present a spatial risk assessment for shallow coastal areas around Antarctica using network-based metrics derived from worldwide activity of Antarctic-going vessels. Data on activity in the Southern Ocean and worldwide port calls were used to create a transport network for ships that visited the Antarctic Treaty Area from 2014-2018 inclusive. The network quantifies previous estimates of much higher ship activity in the Antarctic Peninsula region, especially from South America, but also captures substantial ship connectivity to the Arctic and temperate Northern hemisphere ports, which may have been overlooked as donor regions for anthropogenic introductions in the Antarctic region. The tourism, fishing and research sectors represent different risk and may benefit from tailored management responses.

We recommend targeted monitoring of highest risk areas and further quantification of species within pathways to Antarctica (e.g. fouling Antarctic vessels). Moreover, cooperation between operators of different activity types could ensure maximum impact of biosecurity measures in targeted locations.

[1] McCarthy et al. (2019). Global Change Biology, 25(7).

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Treading lightly – Monitoring physical human impacts on glacial sediments, East Antarctica

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The Vestfold Hills in East Antarctica is the third largest ice-free area on the continent. The coastal oasis comprises 400 km² of exposed rock, glacial, marine, and aeolian sediments, and numerous fresh and saline lakes. There is a sustained human presence from Australia's Davis station but systematic information on the vulnerability of this environment to physical impacts, such as walking tracks, is lacking.

We mapped the composition, distribution, and morphology of different landforms across the Vestfold Hills to better understand their variability. We also set up test sites on different substrates to monitor natural recovery from walking tracks over time and to inform an assessment of the vulnerability of these different substrates to human impacts. At these test sites, we analysed a range of near-surface sediment characteristics to determine visual and non-visual changes resulting from foot traffic. Visual changes are the strongest indicator of impact and recovery on heterogeneous sediments such as glacial till. Structure from Motion photogrammetry is a useful tool for capturing baseline information and tracking change over time.

The data highlight the usefulness of substrate mapping, sediment analysis, and Structure from Motion photogrammetry for understanding human impacts, increasing the range of techniques available to track disturbance in ice-free areas. This information is also important as a baseline for current conditions to monitor natural landscape change in a warming climate.

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The use of granular activated carbons for contaminant site clean-up in the Antarctic, and its in situ regeneration for increased longevity and continuous use

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The large surface area, microporous structure, and increased surface reactivity associated with granular activated carbon (GAC) makes it one of the most powerful adsorbent materials used in purification and separation processes. Coinciding with this, its inexpensive nature makes GAC a viable option for the treatment of contaminated sites in remote regions such as the Antarctic. Whether it be utilized within in situ (i.e. permeable reactive barriers) or ex situ (i.e. pump-and-treat) treatment methods, the GAC will remove contaminants from groundwaters, ultimately preventing further spread into the environment.

Despite this, the leading shortcoming of GAC is the limited lifetime for which it can perform. Upon reaching its adsorptive capacity it is no longer effective and is often returned to Australia for disposal and replaced with fresh material. Such continuous changeout of GAC makes the process infeasible due to the high costs associated with transport, and the disposal of exhausted material into landfill leads to the possibility of toxic contaminants leaching into the environment. A more economical and environmentally friendly option is to regenerate the material so that it can be used for several cycles of adsorption and regeneration.

This work discusses how GAC can be regenerated in situ using electrochemical methods. The data presented suggests that it is a beneficial pathway for use in the Antarctic due to its low cost and minimal energy usage. Additionally, when the appropriate reactions are promoted, it is able to fully degrade contaminants, suggesting that the GAC can be used over and over again.

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Future Directions for Research on Contaminant Containment in Antarctica

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The experience of 20 years of work in environmental remediation and contaminant containment in the Australian Antarctic Territories has highlighted the need for further research to reduce the cost and increase the efficacy of deployment of containment and remediation technologies in the Antarctic.

This presentation will focus on the experience gained at Thala Valley, a dig and haul remediation process and the containment of oil spills at the main power house at Casey, a permeable reactive barrier deployment, to examine and justify the need for better understanding of how adsorbents work, both physically and from a microbiological point of view, in the Antarctic and how their performance can be enhanced through in situ remediation to extend their life.

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Permeable Reactive Barriers for contaminant remediation in Antarctica

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Transportation and storage of petroleum hydrocarbons in Antarctica has resulted in numerous accidental fuel spills. Migrating fuel leads to significant impacts to marine and terrestrial ecosystems, whilst typically low soil nutrient concentrations and temperatures result in low rates of natural attenuation.

Permeable Reactive Barriers (PRB's) are a method to contain and remediate migrating contaminant plumes in an efficient and cost-effective manner. Once placed in situ they require minimal energy, monitoring and maintenance.

This presentation discusses parameters requiring optimisation for the design of efficient and effective PRB's. These parameters include; physical dimensions; reactive material selection; and site placement, considering variables such as; site water fluxes; contaminant characteristics and concentrations; and site access. It will also present the results and key learnings from various case studies located at Casey Station, East Antarctica and discuss how these findings may be translated to other sites across the Antarctic continent.

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EPB's initiative on reducing Environmental Impacts of Polar Research and Logistics

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The impacts of human activities to Polar environments are diverse in their scale and in the level to which they are understood. The environmental impacts of Arctic and Antarctic research and logistics varies with type of activity, technology used and the environment in which it takes place, still the Polar community collectively has a responsibility to minimise the negative impacts of its activities.

The European Polar Board (EPB) launched its initiative in 2018 with a workshop for Members and logistics managers at the POLAR2018 conference in Davos, Switzerland. This workshop, focused on plastic use in Polar research, was followed by a breakout session at the 2018 Arctic Circle Assembly, co-convened with INTERACT, titled 'Minimising the footprint of Arctic research'. Discussions at these events led to the establishment of an Action Group on Environmental Impacts of Polar Research and Logistics, which aims to collate best practices and develop practical guidelines for EPB Members and others. These guidelines will be useful to researchers and managers at all scales, from individuals conducting small-scale campaigns, to managers of national Polar research programmes. Guidelines will address all aspects of research and logistics activity in the Antarctic and Arctic. The EPB initiative recognises the important challenge to reduce current environmental impacts in Polar research and logistics, without compromising on research quality or safety.

This poster outlines the priorities and outcomes that have emerged from the EPB Action Group on Environmental Impacts of Polar Research and Logistics, and detail plans for its future work.

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A call for protection of a growing Antarctic ecosystem service: Blue Carbon gains on Antarctic Continental Shelves are an increasing negative feedback on climate change

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The reduction of seasonal sea-ice extent, retreat of marine terminating glaciers and loss of ice-shelves are allowing new and longer lasting phytoplankton blooms over shallower waters, and opening up habitat for benthos. Zoobenthos have increased feeding and growth duration. The net results are increases in carbon drawdown from the atmosphere into phytoplankton and carbon storage in benthic invertebrates. Although carbon sequestration – defined as removal of carbon from the carbon cycle for hundreds or thousands of years – is likely to be only a small percent of the carbon captured, the area of sea floor where this is taking place is very large and increasing. The number of ice-free days, and thus the number of days the bloom is available for feeding duration potential, is crucially increasing across shallower shelf waters where benthos is in direct contact with the bloom. This is further compounded by the predicted increase of growth rates that may double with a moderate (1°C) increase in sea temperature. However, new and increased coastal productivity faces considerable threats (harvesting, climate spikes, pollution etc) some of which can be reduced through pre-emptive action. We suggest incentivising Antarctic Blue Carbon protection by building a ‘non-market framework’ via provisions in the UNFCCC Paris Agreement. This could be connected and coordinated through the Antarctic Treaty System to promote and motivate member states to value the ecosystem service Antarctic Blue Carbon provides.

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Revisiting the moss flora of Admiralty Bay (King George Island) Antarctica

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The Antarctic Continent has 13.661.000 km2. It's the most inhospitable place on Earth because it's the coldest, highest, driest and it has the largest and most extensive layer of ice on the planet. Within the archipelago of the South Shetlands Islands is King George Island, where Admiralty Bay is located. The bay has 122.08 km² of surface and the vegetation is mainly cryptogamic, but also tree species of angiosperms. In the process of revisiting the Management Plan for Admiralty Bay, of the 116 species of mosses found in the Antarctic, a total of 63 species of moss were found, divided between 33 genera and 17 families. Other than that, 8 new occurrences were found for the region, Brachythecium austroglareosum (Müll. Hal.) Kindb., Gemmabryum dichotomum (Hedw.) J.R. Spence & H.P. Ramsay, Dicranella campylophylla (Taylor) A. Jaeger, Campylopus vesticaulis Mitt., Schistidium lewis-smithii Ochyra, Pohlia wilsonii (Mitt.) Ochyra, Schizymenium pusillum (Hook. f. & Wilson) A.J. Shaw and Notoligotrichum trichodon (Hook. f. & Wilson) G.L. Sm. Considering the total number of species of mosses in Antarctica, the Bay area houses about 54% of all Antarctic moss species, a highly significant number, considering the size of the Bay. The human influence has grown lately with more cruise ships and tourists visiting the area, this can impact negatively the local ecosystems. From the results presented, it is possible to conclude that the diversity of mosses occurring in the Admiralty Bay is high, generating a need for environmental monitoring to preserve the species richness to the site.

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The Scott Base Redevelopment Environmental Monitoring Programme: A Multidisciplinary Approach

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Scott Base opened in 1957. 60 years on, it is reaching the end of its functional life.
The Scott Base Redevelopment (SBR) is the largest project ever undertaken by New Zealand in Antarctica.
The Antarctic Treaty System requires a Comprehensive Environmental Evaluation (CEE) before redevelopment begins. The CEE is underway, supported by a monitoring programme to verify the accuracy of the CEE's impact assessment and detect unforeseen impacts.
In the austral summers of 2018/19 and 2019/20, a multidisciplinary team established an environmental baseline against which future natural and SBR-related changes will be measured.
In 2018/19, 25 monitoring plots were established around Scott Base. They were selected by stratified sampling. Biodiversity surveys, chemical, spectroradiometry, and microbial DNA analysis of soils were completed. Three seals cameras and 12 dust collectors were installed. A multispectral imagery drone survey captured vegetation and surface disturbance.
In 2019/20, the plots were re-visited for vegetation assessments and sampling of invertebrates, soil, dust, microplastics, and meltwater. Five monitoring plots were established as control sites at nearby Cape Evans. Three marine monitoring sites were established to quantify seafloor biodiversity, assess contaminant concentrations in four sentinel species, and measure water currents to understand the potential for sediment and contaminant transport. The sites were selected based on previous research in consultation with Antarctica New Zealand to identify the most likely locations to be impacted by SBR.
The draft CEE and fieldwork findings will be presented at the 2021 Committee for Environmental Protection.

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Overview of Environmental Remediation Research for improved environmental protection within the Australian Antarctic Program

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A legacy of land and coastal marine pollution exists in Antarctica following decades of human occupation and activities. Hydrocarbon contamination of soil and water is most common, while abandoned stations, legacy waste disposal sites and ongoing wastewater discharges cause impacts through multiple contaminants (e.g. metals, polychlorinated biphenyls, fuels, inert and putrescible waste, ammunition and laboratory chemicals). Antarctica's extreme environmental conditions and remote location makes the clean-up of contaminants difficult and resource intensive. Past clean-up solutions have often relied on all contaminated material being excavated and returned to Australia for treatment and disposal. However, where possible, on-site remediation is preferable to provide a sustainable solution for site restoration – ensuring soil, once remediated, remains in the rare ice-free areas where it is most ecologically valued. For over 20 years, scientists and engineers as part of the Australian Antarctic Program have been conducting applied human impacts and remediation research to develop procedures and technologies that reduce environmental impacts from chemical contaminants in the Antarctic. This talk will provide an overview of our progress in developing, designing and applying cost-effective remediation technologies for Antarctic and subantarctic regions, and highlight the full scale application of these techniques using a number of case studies. Research outcomes inform the guide for best practice environmental assessment and remediation in Antarctica, the Antarctic Clean-Up Manual, and can be applied to the clean-up of a range of impacted sites across Antarctica.

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Where science meets policy: The Antarctic Clean-up Manual as a case study in protecting the Antarctic environment

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One of the key obligations of the 1991 Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol) is the clean-up of "past and present waste disposal sites on land and abandoned work sites of Antarctic activities" unless clean-up would result in greater environmental impact.

To assist Parties in addressing their clean-up obligations, in 2013 the Committee for Environmental Protection developed the Antarctic Clean-Up Manual. The Clean-Up manual provides scientifically proven guidance and practical resources that National Antarctic Programs can draw on to clean-up a range of contaminated sites in Antarctica. Recognizing the on-going nature of Antarctic contaminant risk assessment and remediation research, the manual is an evolving central resource, available online, and updated and added to as "new work, research and best practice emerges". Input from the scientific community is therefore essential to the continuing development and improvement of the Clean-Up manual.

Here, we present jointly on the Clean-Up manual as a case study for the effective and ongoing integration of science into environmental policy for Antarctica, providing both a science and policy perspective. The current components of the manual are presented, along with a discussion on priority research needed to strengthen the manual into the future. Finally, we promote the Clean-Up manual as a best practice tool for environmental managers and policy makers in order to support the effective and timely clean-up and remediation of sites across Antarctica, and the ongoing protection of the Antarctic environment.

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The polychaete reefs of Ellis Fjord – a vulnerable and unique benthic community in the Vestfold Hills, East Antarctica

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In 1985 a survey of benthic communities in Ellis Fjord (Vestfold Hill, East Antarctica) discovered a large reef of polychaete worms unlike any other encountered anywhere on Earth. The reefs are comprised of thin (3 - 5 mm diameter) but long (estimated 0.5 – 1 m) calcareous tubes of Serpula narconensis, a polychaete species distributed in Antarctic and sub-Antarctic seas, but normally in small isolated clumps. These reefs were estimated to extend for over 8 km in the lower reaches of the Fjord and cover the bottom from 5 to 30 m deep. These reefs are also home to an incredible density and diversity of epifaunal invertebrates including urchins, crinoids, holothurians and prawns, as well as fish. A survey conducted in 2019 confirmed the continued presence of these reefs and will provide data to determine whether any changes have occurred in this community.

The unique environmental conditions of Ellis Fjord may have afforded these communities protection from physical disturbance which has allowed them to flourish, possibly for millennia. A narrow and shallow entrance to the fjord, which combined with strong tidal currents moving through the narrows and offshore winds prohibits the entrance by any floating ice. In addition it is hypothesised that the narrow entrance also discourages the entry of Weddell seals which are known to disturb the seabed while foraging for fish and prawns in coastal waters, particularly during breeding season. This rare and vulnerable community is worthy of consideration for special protection status such as an ASPA.

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Protecting Antarctica through Co-production of actionable science: Lessons from the CCAMLR marine protected area process

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Global threats to ocean biodiversity have driven international targets calling for a worldwide network of marine protected areas (MPAs). In line with these targets, the Commission on the Conservation of Marine Living Resources (CCAMLR) has been working towards adopting MPAs in the Southern Ocean. CCAMLR is considered a leader in science-based management and has been guiding the way on international MPAs. The west Antarctic Peninsula, threatened by climate change and industrial fishing, has been a priority area for MPA planning in CCAMLR. Since 2011, Chile and Argentina have worked to develop an Antarctic Peninsula MPA proposal which they submitted to CCAMLR in 2018. We use the Antarctic Peninsula MPA proposal process as a case study for understanding the science-policy interface in this international conservation regime. Specifically, we use existing frameworks for co-production of actionable science to examine the Antarctic Peninsula MPA process. We show that the Antarctic Peninsula MPA Proponents engaged in a highly collaborative, transparent, and science-based process which exemplified best practices for actionable science and co-production. Despite following best practices for actionable science, the MPA proposal has not yet been adopted, largely due to political barriers. We elaborate on the importance of co-production of actionable science and its effectiveness as well as to limitations in the Southern Ocean and beyond. Finally, we highlight that science-policy best practices may not be sufficient to drive consensus and the ultimate need for political will in the decision-making underpinning MPA designation in the Southern Ocean.

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Further developing the terrestrial Antarctic Specially Protected Area system using Systematic Conservation Planning

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Systematic Conservation Planning is regarded as an effective and well-developed mechanism for facilitating the development of protected areas globally. To date, however, its application in Antarctica has been limited. In July 2019, SCAR and the Committee for Environmental Protection (CEP) convened a workshop on further developing the Antarctic protected area system, where discussions included the inputs, benefits and challenges of applying a systematic conservation planning process to Antarctica. The findings of this workshop were presented to the XXII CEP meeting which subsequently encouraged research to build on the existing body of scientific evidence and to support the further development of the protected area system.

In response to discussions in the multi-stakeholder workshop, and subsequent encouragement by the CEP, work has now begun on applying the principles of systematic conservation planning to terrestrial Antarctica. Here we report on the initial stages of this continent-wide research, including data acquisition, software and challenges. We show that the data that are currently available as potential inputs to a systematic conservation planning process are now extensive, and range from existing spatial layers to more recent data, including continent-wide, spatially explicit data on biodiversity distribution (actual and predicted), wilderness areas, type localities and habitats. We highlight that despite the challenges inherent in combining complex and disparate data from multiple sources, systematic conservation planning processes can be aligned with guidance in Annex 5 of the Environmental Protocol, and have significant potential for improving environmental protection through the further development of protected areas in Antarctica.

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Antarctic Science - Global Connections

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SESSION 35

THE CHANGING FACE OF ANTARCTIC TOURISM

INTERNATIONAL SCIENCE COUNCIL SCAR SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

Daniela Liggett
Karen Alexander, Marisol Vereda

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Exploring the association of trip modalities with experiential and learning outcomes of Antarctic tourism

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Antarctic tourism plays a crucial role in creating meaningful interactions between tourists and the Antarctic environment. The way tourists experience this last frontier is vital for fostering environmental awareness and public support as Antarctica is under increasing threats.

Antarctic tourism is growing and transforming. The emergent air-cruise modality, a variation of the traditional cruise modality, is diversifying not only the mode of transport but length and nature of itineraries and activities. Understanding the interactional components of Antarctic tourism and how they shape experiential and learning outcomes is critical as these could influence tourists' awareness, attitudes, and behavior. Our study was guided by the overarching question: how modalities and their associated trip characteristics influence the experiential and learning outcomes of Antarctic tourists?

During the 2019-2020 season, we deployed PRE and POST tourists' surveys using 13 categories of questions related to experience, emotions, knowledge, and attitudes. As of the end of February 2020, we have collected 200 surveys and we expect to collect 100 additional. Experiential outcomes will be analyzed by conventional satisfaction measures and the autobiographical memory scale. Learning outcomes will be analyzed using measures of knowledge, beliefs, attitudes, and behavior. The association of modalities with the outcome variables will be examined by statistical analyses like T-tests, MANOVA, and ordinal regression.

We expect that the results of our analysis could contribute to a better understanding of Antarctic tourism in its evolving forms. This would inform tourism management, especially modality-linked tourism educational programming and communication – two essential components of Antarctic tourism.

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Towards a broader dialogue on the management of tourism in Antarctica

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Antarctica is an increasingly popular tourist destination and attracts over 75,000 visitors in the summer. Currently, the number of tourists going to Antarctica is determined by market forces. The upward trend of the last decade indicates that tourist numbers will continue to rise, and the activities in which they engage will further diversify. This increases the risk of negative impacts on the environment, and heightens the need for the timely, effective management of the industry. Tourism is currently governed through the Antarctic Treaty System, whose decision making process is lengthy and slow. There are concerns this process, left unchanged, cannot adequately respond to the huge increase in tourist numbers expected in the next few years. To this end, the Polar Institute of the Wilson Center proposes itself as a novel platform for management discussions, inviting collaborators to a neutral forum to discuss and create innovative solutions that can assist policy makers in the ATS. Since 1968, the Wilson Center has promoted open dialogue and non-partisan insights to create actionable ideas in many regions of the world. Into this 'think-tank' environment, we propose bringing together policy makers, environmental scientists, ATCP delegates, science communicators, and lobby groups with vested interests in Antarctica, such as the tourism industry, to seek timely, realistic and practicable outcomes that can fit into the framework of the ATS.

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The growth of Chinese tourism to Antarctica: a profile of their connectedness to nature, motivations, and perceptions

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Antarctica emerged as a tourism destination only some 50 years ago, the annual number of visitors has increased and the nationalities of visitors have shifted over the years with an increasing number of visitors from the People ' s Republic of China. However, there is a lack of empirical studies on Chinese visitors ' motivations and perceptions of their Antarctic visits. This study reports on a preliminary investigation of the reasons why Chinese visit Antarctica, their post-visiting perceptions of the region and their potential anthropogenic impacts on the Antarctic environment. The study is based on data collected from 120 passengers who travelled on two Antarctic voyages on fully
Chinese chartered cruises during the 2017/18 Antarctic season. The results show that curiosity about Antarctica is the major motivation for tourists from China to visit Antarctica. The majority of respondents indicated a sense of commitment to the protection of Antarctica after their Antarctic visit but because citizens of mainland China may have a different understanding of environmental protection. The close supervision and guiding during their shore visits are recommended.

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New Phytoplankton Communities Revealed in Coastal Antarctica Using a Citizen Science Approach with Tourism

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The Antarctic Peninsula is one of the fastest warming regions in the world, with over 87% of its glaciers in retreat. Documenting the seasonal and annual dynamics can be difficult due to extreme weather conditions, large icebergs, and limited research vessels. Gathering time-series data throughout the austral spring, summer, and fall can be achieved through the framework of citizen science (CS). The Antarctic tourism industry includes a fleet of vessels that visit the Peninsula November through March. We developed a CS program— FjordPhyto—to leverage these vessels as platforms to gather data and to engage the traveling community in the legacy of polar research. This study represents the first attempt to understand phytoplankton succession at coastal sites and to date, more than 300 samples have been collected from 19 locations with the help of more than 3000 travelers. The coast is proposed to have hotspots for biodiversity with large aggregations of krill, whales and benthic fauna fueled by the phytoplankton blooms. Variability in the amount of meltwater coming from melting glaciers is expected to favor different phytoplankton assemblages. A shift in this food source could have ramifications to carbon available to higher trophic levels in the nearshore food web. Results from the first years sampling were unexpected: Existing observations report diatom dominance in this region; however, the blooms encountered in this study were from flagellated taxa, documenting the first record of a dinoflagellate bloom in the region. Results highlight the importance of nanophytoflagellates and a shift in the different dominant taxa provide a first approximation of how much organic matter is available through the phytoplankton communities sampled. We show that CS is a valid tool that can enhance research in Antarctica, while also providing an enriching experience to travelers interested in learning more about science in polar environments.

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Thawing Out Antarctic ambassadors: Who Are They and What are They Doing?

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The number of Antarctic tourists increases annually, and recently exceeded 50,000 during the 2018/2019 season. Antarctic tour operators emphasise that Antarctic tourism is an opportunity to "create a corps of Antarctic ambassadors" who will promote the protection and conservation of Antarctica. However, scholarly research directed at examining the concept of Antarctic ambassadorship has been limited and, to date, neither an agreed upon definition of the term Antarctic ambassador nor any substantial understanding of what it implies exist.

Our research investigated the concept of ambassadorship in the Antarctic context, drawing on a database that tracked the usage and evolution of the term. To build this database, we reviewed a broad range of sources, including scholarly literature, ATCM reports and online media such as newspapers, blogs and social-media platforms. In total, we identified 365 sources. Due to the relatively small number of academic research directly addressing Antarctic ambassadorship, online media represented the majority of the sources reviewed in this study.

We used qualitative and quantitative analyses to examine (a) who was commonly associated with the term Antarctic ambassador, (b) what context it occurred in, and (c) the underlying intentions of its use. Our results highlight that the term does not commonly occur naturally in language but is frequently used as a title, and primarily associated with organisations, including tourism operators, in their efforts to promote themes of environmental protection or Antarctic research. The key ambassadorship characteristics identified were Connection, Knowledge, Passion, Representation, Champion, and Support (through communication and behaviour).

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Transforming tourists' relationship with Antarctica through culturally informed mediation practices

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Unlike most destinations, Antarctica is not a place that many tourists can encounter independently. Travelling primarily on cruise ships to selected sites in the Antarctic Peninsula, most tourists experience the continent in a carefully curated way, with onboard lectures and activities and guided excursions framing their encounters with the environment. However, despite increasing scholarly attention to polar tourism, the nature of this mediation and its role in tourists' experience of Antarctica has yet to be systematically examined, and we are only at the beginning of understanding how cultural and national background interacts with this mediation. Cultural attitudes to the continent can be remarkably varied. Scott, Shackleton, and Mawson might weigh heavily on the British and Australian imaginations, but contrasting exploration histories, geopolitical relations, and attitudes to wilderness mean that travellers from other countries (such as India, China, Norway, or Argentina) could understand the region very differently.

This presentation outlines a forthcoming collaborative project between a tourism operator and an academic team aiming to discover how cruise-ship tourism can foster a positive and culturally informed relationship with Antarctica among diverse groups of visitors. Through in situ fieldwork, including interviews and participant observation, the project will examine how the typical Antarctic tourist journey, with its interpretive activities as well as its multi-sensory experiences, shapes the experience of people of different national and cultural backgrounds. The presentation outlines the project's rationale, objectives, methodology and potential outputs.

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Travel Guide Books and the Antarctic Tourist Experience: A Textual Analysis of Lonely Planet "Antarctica"

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The expansion of the Antarctic tourism industry in the last few decades has been accompanied by a small but growing corpus of travel guidebooks. These range widely in purpose and intended readership, from Dixie Dansercoer's "practical handbook" for independent expeditioners to Peter Carey and Craig Franklin's "cruising guide" for visitors travelling to the Antarctic Peninsula and other popular destinations. While a sizeable body of scholarship focusses on Antarctic tourism, the role of travel guidebooks in this industry remains largely unexamined.

This presentation offers a brief, broad-scale textual analysis of the most mainstream title in the genre, Lonely Planet "Antarctica." First published in 1996, and now in its sixth edition, this guidebook includes many of the features associated with other Lonely Planet titles, including a list of top tourist sites, suggested itineraries, and even the standard section called "On the Road." Nonetheless, as this phrase suggests, Antarctica's unique features as a travel destination put significant strain on the series' conventions. How does a brand built on the idea of independent travellers who use travel guides to construct bespoke experiences deal with a continent that tourists almost always experience as part of a highly controlled cruise-ship journey?

Textual analysis is of course only one approach to understanding the ways in which travel guides form part of Antarctic tourism. This presentation concludes by suggesting further means through which Antarctic travel and tourism scholars might incorporate tourist guide books into their research.

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Changing distribution and intensity of Antarctic tourism into the future

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Antarctica is home to unique species and remote wildernesses found nowhere else on the planet, yet it is faced with increasing threats from a changing climate and rapidly growing human activity. Nature-based tourism is an opportunity to connect people with species and ecosystems in conservation need, but can also pose substantial damage to the natural environment itself. This dilemma is prominent in Antarctica. Yet, remarkably little is known about the distribution, intensity and possible future trajectory of Antarctic tourism. By modelling the characteristics of potential landing sites in combination with two Intergovernmental Panel on Climate Change (IPCC) climate forcing scenarios, we make projections about how the distribution of landings may change. Our results suggest that new landing sites suitable for tourism may become accessible in relatively remote parts of the Antarctic coast, which are currently rarely visited, and that the intensity of landings at some existing tourism locations may also increase. Increased risk of non-native species establishment with climate change will be exacerbated by increased introduction opportunity from human activity at a growing number of sites and in new regions across the Antarctic continent. These synergies may also facilitate the potential intraregional transport of native species. Yet despite these potential risks, tourism could play a critical role in Antarctic conservation through ambassadorship and increased public awareness.

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Delivering responsible Antarctic tourism - past lessons for future action

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The International Association of Antarctica Tour Operators (IAATO) was founded in 1991 with a mission to advocate and promote the practice of safe, environmentally responsible private-sector travel to the Antarctic. Initially formed by seven operators, six vessel and one land-based, IAATO has grown to encompass around 50 operators representing the majority of companies offering opportunities to experience Antarctica today. IAATO self-manages its activities to fulfil its mission, working within the framework of the Antarctic Treaty System, particularly the Environmental Protocol. Most travellers still visit the Antarctica Peninsula on vessels that follow a traditional model that was established in the 1960's. However, over the decades, drivers such as emerging markets, changing economic and environmental conditions, regulation, diversification of activities and past periods of growth have required IAATO to continually evolve to meet its objective that its planned activities will have no more than a minor or transitory impact on the environment.

IAATO maintains one of the most comprehensive databases on human activity in Antarctica, annually reporting to the Antarctic Treaty Consultative Meeting to facilitate discussions about managing it. We use examples to describe how IAATO has responded to challenges and opportunities in the past to prepare for current and projected tourism growth. We will outline existing obstacles, as identified by the industry, illustrating how IAATO is using science and engagement to meet its objectives. This includes long-term monitoring, applied practical management in the field, providing policy makers with appropriate information and managing travellers' expectations to create ambassadors for Antarctica's continued protection.

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Scientific engagement increases polar awareness amongst travellers: Examples from the expedition ship operator Hurtigruten.

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Hurtigruten, a member of the International Association of Antarctica Tour Operators (IAATO) and AECO (Association of Arctic Expedition Cruise Operators), has been visiting the vulnerable polar environments for two decades, witnessing the effects of Anthropocene footprint and climate change. Aware of our role as a stakeholder in promoting the long-term protection of these regions, we promote safe and environmentally responsible operations, invest in the understanding and conservation of the areas we visit, and focus on the enrichment and education of our guests. This has become increasingly important in more recent times, as tourism and the number of ships in the polar regions has grown significantly. Much needed scientific data collection in these areas is challenging due to remoteness, a harsh environment and high operational costs. As such, we have established collaborations with numerous scientific institutions and support the scientific community by providing our ships as platforms for spatial and temporal data collection, transporting researchers and equipment to and from their study areas and participating in Citizen Science projects. Our ships are equipped with Science Centers that engage polar travelers in research and enable collaborating scientists to collect high quality data and perform preliminary analyses in situ.
We present results from such collaborations and demonstrate how, when combined with structured, interactive learning opportunities, they facilitate globally important research while positively affecting our guests' attitudes and behaviors after they return home.

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Tour Guiding in Antarctica: From Policy to Practice

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Each year, decisions on the management of Antarctic tourism take place at high-level meetings within the Antarctic Treaty System; these guidelines and recommendations inform the activities of those who travel to the Antarctic Region on commercially organized voyages and expeditions. In addition the International Association of Antarctica Tour Operators (IAATO) promotes advocacy and responsible tourism management within its membership, providing guidelines and resources to ensure safe visitor management. This paper examines the role of the Antarctic tour guide as the front-line actor in interpreting and enforcing these directives before Antarctic visitors, and asks how guides interpret Antarctic governance in the cruise setting.

We investigate where guides see themselves positioned within the existing structures of Antarctic governance, and the ways in which they act as mediators between theory and practice. Guests undergo mandatory IAATO briefings and biosecurity checks prior to any landings, but how is this contextualised within the wider Antarctic governance framework? How aware are guides of the wider governance structures at play in Antarctica? And to what extent do guides see providing this context as their responsibility? Through focussed interviews with Antarctic tourism guides with a range of experience in the industry, we analyse the connections between policy decisions and on-the-ground practice and reflect on the end-user side of tourism governance decisions.

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Ushuaia´s role in the Argentine Antarctic policy and the influence of capitalism in the city through Antarctic tourism in the 20th century

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The objective of this research project is to analyze factors and actors that regulate Ushuaia's role in Argentine Antarctic policy and global Antarctic tourism. I have taken a constructivist approach to explore and explain the different social, political, economic and scientific transformations that Argentina has undergone in the 20th century, with a focus on the position taken by the Argentina in Antarctic policy and Ushuaia´s role at each stage of the development of Argentina's Antarctic sector. Changes in Ushuaia are assessed in comparison to the trends of the global market and Argentine economic policies. Although Ushuaia is considered to be one of the Antarctic gateway cities and is visited by more than 90% of Antarctic tourists, fulfilling Argentina's geopolitical-economic ambitions and living up to the expectations of the commercial tour operators, being seen as an Antarctic city is not enough. This research argues that Argentina, as one of the hegemonic actors in Antarctic policy, is not the only actor to determine Ushuaia's relationship with the Antarctic in the 20th century.

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SESSION 35

THE CHANGING FACE OF ANTARCTIC TOURISM

Daniela Liggett
Karen Alexander, Marisol Vereda

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SESSION 36

ANTARCTIC HERITAGE

Maria Ximena Senatore
Michael Pearson,Rebecca Hingley

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Fully immersive virtual reality experience of Sir Edmund Hillary's Antarctic hut

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Antarctic Heritage Trust partnered with Auckland University of Technology (AUT) to create a ground breaking virtual reality experience of Sir Edmund Hillary's Antarctic hut which was launched in early 2020. The virtual reality experience allows people to step inside Hillary's (TAE/IGY) Hut and to explore the first building at what is now New Zealand's Scott Base. Stories of Hillary's 23 man team and their mission to further science and exploration in the world's most extreme environment feature within the experience and through accompanying material. It is a fully interactive experience, which includes a guided tour through the hut; it celebrates New Zealand's first presence in Antarctica as part of the Trans- Antarctic Expedition and International Geophysical Year.

The authors used a combination of photogrammetry and lidar technology to map the interior and exterior of this historic hut and create this virtual reality walk-through. By delivering a highly affordable, accessible and immersive virtual reality experience, this research pioneered new science communication tools to improve public and media engagement with Antarctic heritage and climate issues. This presentation will share more about this exciting research and how being at the cutting edge of new technologies, can bring important heritage sites and their stories alive for the public.

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Contemporary conservation theory and methods for the preservation of archaeological remains recovered in sealer's shelters on Livingston Island

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The proposal aims to present research on the conservation methodologies for the archaeological collection excavated in archaeological sites on Livingston Island (South Shetland Islands), dating from the 19th century and resulting from the activity of seal hunters in the region. The collection contains very fragile materials, preserved due the cold climate and the specific environment context. The remains are fragments and objects characterized by the simplicity of the common worker classes of the period. Are originally dense and with few aesthetic details, made to be cheap and sturdy. The collection also contains artefacts made provisionally, in response to the immediately needs. However, the classical conservation methods has been focused on remains related to artistic and historical narratives, coming from intellectual and economic elites and based on principles such as the "aesthetic and historical originality". Only on the last three decades, from the new dialogues between Conservation and the Human Sciences, as well as the Anthropology, becomes possible for the contemporary conservation theory consider the subjective social dimension existing in the decision of treatments and results. It also began to be possible to think of methods focused on the identity and cultural information existing in the Livingston Island archaeological sites

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The Geopolitical Deployment of Historic Sites and Monuments: Ulterior Agendas for Antarctic Heritage.

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All heritage, no matter where in the world it is found, is constructed by someone for a particular purpose – so who is heritage in Antarctica constructed by, and what is it for? Some historic remains on and around the frozen continent have been multilaterally and officially recognised as possessing historical significance. These sites and monuments, of which there are now almost 100, are recorded on the register for formal Antarctic heritage, that is, the List of Historic Sites and Monuments. This paper will consider three ways in which states might deploy Historic Sites and Monuments (HSMs) for geopolitical means: HSMs as a means to exercise de facto sovereignty; HSMs as a means to nation-build; and HSMs as a means to evade environmental obligations. There is no doubt that Antarctic states are genuinely invested in the preserving and conserving of Antarctic heritage, but by exposing their potential ulterior agendas it is possible to gain a deeper understanding of how the governance of Antarctic heritage has progressed, and where it might lead in the future. In an increasingly uncertain physical, as a well as political, climate that stands to threaten the very existence of Antarctic heritage, it is imperative to remain critical of, and continually better, the decisions and processes that manage it.

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Antarctic visual cultural heritage: are collections stagnating?

Adele Jackson[1]
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Several national art collections include individual artists' work made in response to time spent in Antarctica, notably, a small number of museums and Antarctic organisations across the world house archives and collections devoted to Antarctic visual art. Archives and collections are important sites of knowledge for current and future generations; therefore, it is vital to understand whether organisations are actively acquiring artworks that reflect cultural and critical engagement with Antarctica. The management and development of these collections can vary considerably, with resources and organisational priorities affecting acquisition decisions.

This paper draws on desk-based research and 56 semi-structured interviews with cultural professionals, Antarctic researchers, senior Antarctic organisation representatives, and exhibition visitors collected during a project exploring the value of artists working in Antarctica. The research identifies that artworks are an important legacy and dimension of Antarctic cultural memory. Further, archives and collections have a substantial and internationally significant role in preserving and making available that legacy and cultural memory. The high potential for stagnation and lacunae in collections will be examined in relation to the management and acquisition challenges that organisations face. The research offers a step towards a comprehensive understanding of the location, content, and acquisition activity of Antarctic visual art archives and collections.

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A system apart? Creating and managing cultural heritage in Antarctica

Kati Lindström[1], Lize-Marie van der Watt[1], Bob Frame[2], Daniela Liggett[3], Ricardo Roura[5], Dag Avango[4]

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This paper critically engages with the study of heritage management within the Antarctic Treaty System, examining the evolution of the relationship between the ATS, national and international heritage management systems, as well as tourism. We discuss three key issues: First, we consider the extent to which domestic heritage processes and understandings of natural and cultural heritage have been neglected, in research and international practice of Antarctic heritage. We ask how has this affected our understanding of the historical role of heritage in the ATS and the efficiency of heritage protection? Second, we take a closer look at some of the idiosyncrasies of official cultural heritage protection within the ATS as compared to other international heritage management frameworks. What are the consequences of heritage protection being subsumed under an environmental protection system? What conceptual and management tools that are available to cultural heritage managers in other political contexts are excluded in the process? We argue that in some aspects, these systems are not compatible. Third, we argue that tourism has historically played and continues to play an important role in driving changes in heritage management (for example through guidelines and plans). Cultural heritage is part of a larger assemblage of elements of tourism experiences in Antarctica, and likely to increase in importance. This integral tourism experience defies divisions like natural and cultural or tangible and intangible heritage and can thus push the ATS towards a bigger acceptance of the heritage vocabulary as used by ICOMOS and other international agencies.

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Audiovisual management of the Antarctic Heritage

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We live in a visual age. Audiovisual narratives are part of our everyday life and tell us something about the world. Such narratives shape our understanding. This paper explores the audiovisual narratives of the UK Antarctic Heritage Trust, the NZ Antarctic Heritage Trust, and Mawson´s Huts Foundation. In doing so, we examined their websites and posts on YouTube, Instagram, Facebook, and Twitter. The results highlight their main topics of interests and focus on their views about the environment changes in Antarctica, the challenges for the management of Antarctic Heritage, and the future of the Antarctic Treaty System. This presentation aims to evoke reflections and discussions about the role of audiovisual narratives in the management of the Antarctic heritage.

835

The probable future of Antarctic heritage and the emerging paradigm of triage and reconciliation to large scale loss as a result of climate change.

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Until recently most Antarctic monuments and sites have enjoyed the relatively stability of cold dry environments. These historic conditions which are associated with low humidity, stable permafrost and predictable sea-ice formations, have been providing relative immunity from the sorts of decay mechanisms that are more commonly encountered at temperate sites worldwide. Sometime around 1976 however, things began to change: that was the last year the earth was cooler than the 20th-century average. Since then polar temperatures have been rising at more than twice the rest of the planet, and this year we witnessed the highest temperatures ever recorded in Antarctica (Barr, 2011, Brazilian Antarctic Program, 2020; Bush et al., 2019; "NASA" 2019,).
Increased visitor impacts (a consequence of easier access), disturbance of the archaeological record via cryoturbation and biodeterioration of historic fabric, including molds, soft rot fungi and wood aggressive insects, are some of the predictable outcomes of global warming (Harmsen, 2017; Olynyk, 2014; Wolff 2013). If we want to better understand the changes taking place in Antarctica, we need only look north. In parts of the Arctic, artefacts are currently being released from their thawing landscapes faster than they can be documented or collected, while coastal erosion exacerbated by wave action, reduced sea-ice volumes and increased storm events is either threatening or destroying many other sites (Barr 2008, 2011; Goose et al. 2018; Harmsen 2017). This paper will explore the implications of climate changes for Antarctic heritage and what we can learn from the experiences of our northern colleagues.

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Antarctic Can Conservation: Maintaining ‘Spirit of Place’ in the Expedition Bases of the Ross Sea Region

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For the last decade, the New Zealand based Antarctic Heritage Trust (NZAHT) has managed a programme of interventive conservation to the buildings and artefacts comprising the four Heroic-Era expedition bases of Scott, Shackleton and Borchgrevink. More than 70 heritage professionals have worked in Antarctica on the project, and more than 20000 artefacts have been assessed and treated. With so much activity and intervention at the site, one of the greatest challenges aside from the remote location and difficult weather, has been how to maintain the integrity, and tremendous sense of place which each of these sites intrinsically holds. This poster introduces the challenges of maintaining ‘Spirit of Place’ at the sites, focussing on the canned food collection as a particular example.

Keywords: Cans; Canned; Antarctica; Heritage; Trust; Conservation; Food; Heroic-Era.

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Game Engines, Photogrammetry and Deep Learning for Antarctic Heritage Visualization

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Antarctic Heritage presents unrivalled opportunities for contemporary computational visualization techniques. These range from compelling immersive heritage experiences for the general public, through to the more exacting development of accurate digital archives for scholarly use.

Game engines have a wide variety of heritage applications as development environments for computational humanities, digital museology and GLAM-sector applications. Reconstruction of historic Antarctic sites using satellite and other geophysical data in concert with photogrammetric scene reconstruction enable the construction of physically accurate heritage site models. These can be displayed as immersive screen experiences (e.g. VR, Augmented Reality and Dome environments) and afford novel visual analytics approaches to Antarctic heritage data. Associated historical textual, map, photographic and film materials can be restored, animated, translated into 3D scenes and actors, and colourised using machine learning techniques ('Deep Learning') employed in the film, special effects and games industries.

Immersive interactive simulations that embed historic materials demonstrate new ways of interacting with museum collections and scientific archives, new digital methodologies of historical scholarship and effective ways of exposing fragile archival materials for general and specialist audiences.

Interactive post-cinematic narratives suggest novel opportunities for dramatising the experience of significant artefacts, bringing place, biography, history and science alive. Remote environments, both in space and time, become far more accessible and available to contemporary enquiry.

A demonstration model of the Mawson's Huts Historic Site will be presented, using a computer game engine.

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Antarctic Legacy collaborates to celebrate South Africa's Polar heritage with 60th year anniversary of the Antarctic Treaty.

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The Antarctic legacy of South Africa (ALSA) collaborates with various institutions in South Africa to preserve our Polar Heritage. The 60th anniversary of the Antarctic Treaty was celebrated with a few activities. This presentation aims to give a short overview about these celebrations and to emphasise the fact that South Africa has a long standing history with Antarctica since the Heroic Age.
Iziko Museums established a new exhibition - Sentinels of the South. It examines the history, discoveries and current role of South Africa's involvement in the Antarctic region. It take visitors through the history of early Antarctic exploration, and South Africa's role in this and the role these islands play in helping us understand some of the global issues affecting everyday South Africans. South Africa's multidisciplinary Antarctic scientific endeavours, research facilities and flagship research vessel, the S.A. Agulhas II are showcased.
A Launch was held by South Africa as a Gateway country at the beginning of the Antarctic season. ALSA had an exhibition stall and the 360 footage of the South African National Antarctic Expedition (SANAE) IV was launched at this event
60 years ago the first South African National Antarctic Expedition (SANAE) left from Cape Town harbour on the 3rd of December 1959 bound for Antarctica. In commemoration of this first journey – Chris de Weerdt, diesel mechanic of SANAE 1, and Mettie (wife) and Karen Hechter (daughter) of team leader Hannes La Grange – visited Cape Town harbour at East Pier on the 3rd of December 2019.

811

What will remain of the research vessel “Polarstern”? A Strategy of Archival Appraisal for the Documentation of a Workhorse in Antartic Research.

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Since 1982, the German Research Vessel "Polarstern" was 36 times on expedition in Antartic waters. So it can be considered as part of the Antarctic heritage. In view of its age, plans are currently being developed to replace the ship with a new one and to decommission it.

Even though the end of Polarstern's service has not yet been determined, from the point of view of the German archives and against the background of the widely scattered ship documentation, the identification of its important documents must already be considered today in order to be able to hand them down to posterity, after the Polarstern will have been decommissioned. Therefore, a strategy should be developed, with the help of which the responsible archives can identify important ship documents in a coordinated manner and by thus initiate a concerted archiving process.

To this end, an appraisal concept has to be formulated. It should contain a balance of existing Polarstern’s documentation with regard to its document types, scope, storage location and gaps. In addition, the plan should include a documentation profile, with which the archives can appraise the existing ship’s documents in their area of responsibility. Moreover, such a concept should comprise an agreement for an archival appraisal network, where - apart of the document profile - arrangements on membership, responsibilities and further steps in the archival process (archival description, retrieval, public presentation etc.), are recorded.

In the talk, the plan with its elements outlined above will be presented and discussed in detail.

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SESSION 37

THE ATS, INTERNATIONAL LAW, AND GOVERNANCE

Alejandra Mancilla
Patrick Flamm, Julia Jabour, Gabriela Roldán

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Between extension, nationalization, and a ‘Southern Svalbard’? Futures of the ATS in the system of world politics

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After its 60th birthday, the future of the ATS is all but certain. This contribution argues that while simple extension and small-scale adaptations remain distinct possibilities, the ATS will probably not escape the reconfiguration of a range of global legal regimes that pertain to non-sovereign territories and spaces (including, most notably, the seabed and outer space). In order to explore these reconfigurations, the paper first offers a reading of the historical development of the system of world politics in terms of the simultaneous presence of forms of organizing political authority (through, for example, sovereignty, imperial hierarchy, global governance etc.). Based on such a reading it offers a spectrum of possible developments of the political and legal forms pertaining to the Antarctic: multilateral exclusive treaty, multilateral inclusive treaty, international authority (direct or trusteeship), realization of sovereignty claims (open contestation, new territorial delimitation), split sovereignty (the Svalbard model), Antarctic sovereignty. The purpose of this contribution is primarily to open thinking spaces on the future of the ATS and Antarctica based on recent historical-sociological research on forms of ordering in the system of world politics. It is an elaboration of a brief presentation originally delivered in a conference on the future of the ATS held in Buenos Aires in late 2019.

1564

The role of Argentina and Australia in managing the geopolitical tensions within the ATS.

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The Antarctic Treaty System (ATS) arose in response to particular historical contingencies and it has effectively managed geopolitical tensions in the region for nearly 60 years. Argentina and Australia are two of the seven sovereign states which have territorial claims in Antarctica and have played a significant role in the formation of the Antarctic Treaty. Coming from different parts of the world and cultural backgrounds, but with some similar interests, both states are key participants in the international treaties that constitute the ATS. In the early twenty-first century, the institutional and legal framework governing Antarctica is facing a new set of biophysical and political pressures which require innovative approaches to balance a variety of different interests. Therefore, the aim of this paper is to analyse how Argentina and Australia have approached geopolitical tensions during critical moments in the history of the ATS. The paper will highlight similarities and differences in the approach between the two states. In addition, the paper will discuss what lessons might be drawn on the possibilities for Argentina and Australia in managing current and future tensions in Antarctica.

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On sovereignty: a view from Russia into the 2020s

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Moscow has played a significant role in the cohesive management of the Antarctic as an active ATS member. The latent question of sovereignty has remained at the forefront of Russian Antarctic strategy, with Moscow recognizing no existing territorial claims and reserving the right to assert a claim. Under Putin, Russia has reemerged as a assertive strategic player in the international arena. Antarctica is an historical feature of the Russian great polar power identity project - which continues today. Renewed great power politics, in particular, Moscow's position within the rising China and 'new great game' narratives are also evident in Russia's approach to Antarctic strategy. This paper examines the issue of Antarctic sovereignty through a Russian policy lens in order to elicit strategic scenarios for the future history of Antarctica. Can we expect Russia to remain a cooperative, collaborate Antarctic stakeholder? Will Moscow's great power ambitions under the Putin system shape a more assertive, perhaps aggressive, Antarctic strategy? Beyond unpacking the strategic implications of Russian Antarctic strategy, this paper asks the question: how will, how can, the ATS respond to and weather such pressures?

1244

Using international guidelines to improve tourism management in Antarctica

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One of the primary challenges to Antarctic governance is the management of tourism, which could increase by as much as 40% in under a decade. Discussions of tourism at recent Antarctic Treaty Consultative Meetings (ATCMs) have focused on more abstract discussions that have little chance of resulting in concrete outcomes. In this presentation, we will examine a potential means for enhancing Antarctic governance of tourism by using the recently published Guidelines for Tourism and visitor management in protected areas from IUCN as a framework for analysis and discussions. IUCN is a well-respected authority on conservation, and these guidelines synthesize lessons learned from a diverse set of countries.

In our presentation, we will examine the current tourism management system in Antarctica in the context of the IUCN principles and guidelines and identify where it meets or exceeds international best practice and where it falls short. For example, there is a system of site guidelines to manage visits, but the selection of sites is largely opportunistic and reactive. Therefore, we offer suggestions for framing future ATCM discussions on tourism through the lens of implementing IUCN guidelines and filling gaps between the guidelines and the current system. We will also discuss how IUCN guidelines can be adapted for the unique governance system of Antarctica. This will help the ATCM move from conceptual to practical discussions on tourism regulation, and ensure continued protection of the Antarctic environment based on proven strategies.

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Antarctic Hierarchies: Stratification, Status and Socialization

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Sixty years after the signing of the Antarctic Treaty, global power shifts and especially the growing influence of Asian actors are raising the question whether and how the status quo Antarctic order can be maintained. This paper engages with the most recent International Relations (IR) theory scholarship about hierarchies in world politics (Zarakol 2017; Zarakol and Bially Mattern 2015; Bukovansky et al. 2012; Lake 2009).
First, it argues that today's Antarctic order remains a stratified configuration of rights and privileges which centers/constitutes selected states as Antarctic actors with authoritative status. For example, original signatories cannot lose their consultative party status, and unlike any other state territorial claimant states have the right to maintain their claims.
Second, it explores stratified processes, dynamics, and forms of power that shed light on socialization dynamics which are crucial for the accommodation of new status aspirations by actors like China or South Korea: are states buying into the stratified Antarctic order for functional bargains, or because of meaningful social relations that constrain or influence agent choices and behavior, and/or because established Antarctic practices are "cultures-in-action" that produce Antarctic players as such as well as their repertoires for action?
Understanding how socialization works for established as well es emerging actors within this stratified system, is crucial to political analyses of the future of the Antarctic order for scholars and decision makers alike.

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The response of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) to emerging and projected impacts of climate change

Lyn Goldsworthy[1]
[1]*IMAS, UTAS, Hobart, Australia*

Human activities in the Southern Ocean are managed through the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). CCAMLR is a multinational consensus-based Convention and meets annually to determine management decisions relating to fishing activities and conservation in the delivery of its objective. The CCAMLR Convention requires its Members to base its management decisions on a precautionary, ecosystem-based and scientific approach. In recent years, emerging rapid environmental changes likely to be associated with the impact of climatic change have been reported in parts of the Antarctic region, and research suggests ongoing changes and direct impacts on species and habitats of interest to CCAMLR. Such changes are likely to influence CCAMLR's capacity to deliver its objective, particularly concerning the maintenance of healthy ecological relationships between harvested species and those that are dependent or associated, and with respect to minimising or preventing the risk of long-term fishing impacts on the Southern Ocean ecosystem. This paper reviews CCAMLR's management response to this problem thus far, and provides suggestions on possible responses into the future.

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Does the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) use 'Best available science'?

Lyn Goldsworthy[1]
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Human activities in the Southern Ocean are managed through the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). CCAMLR is multinational consensus-based Convention and meets annually to determine management decisions relating to fishing activities and conservation in the delivery of its objective. The CCAMLR Convention requires its Members to base its management decisions on the 'best available scientific advice', and CCAMLR prides itself on taking such a precautionary approach. But is that true? The current stalemate in the adoption and implementation of a network of marine protected areas, the failure to include the possible impacts of rapidly changing environments when assessing management measures for fisheries, and the failure to take the advice of the Scientific Committee on specific fishery proposals raises questions about the Commissions' interpretation and acceptance of the advice from its Scientific Committee as well as the basis of that advice. This paper tracks proposals from consideration by the Scientific Committee, the Committee's advice to the Commission and the Commission's response to review this claim. It analyses instances where Scientific Committee advice is not accepted and identifies trends across categories of decisions, Members' positions and the arguments used. The analysis identifies that 'best available science' is least accepted in proposals concerning issues that extend beyond directed fisheries management, and that particular Members question the basis of the scientific advice more frequently than others. The paper concludes that the Commission of CAMLR is not consistent in its approach to the application of 'best available science'.

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Antarctic Protected Areas and Climate Change

Kevin Hughes[1], Peter Convey[1], John Turner[1]
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Antarctica, and particularly the Peninsula region, is increasingly vulnerable to climate change impacts such as ice retreat and changing species distribution, while human activity is putting increasing pressure on marine and terrestrial environments. Under the Antarctic Treaty System, protected areas can be designated to protect locations of scientific, environmental, historic and intrinsic value (Antarctic Specially Protected Areas; ASPAs) or to encourage operational coordination to minimise environmental impact (Antarctic Specially Managed Areas; ASMAs). We evaluated the effectiveness of current policy and environmental management practices for addressing climate change within the Antarctic Protected Areas System. In general, climate change has been little considered in guidelines for designation and management of the region's protected areas. Climate change impacts are discussed in only 17% of ASPA management plans, with those ASPAs located on the Antarctic Peninsula and Scotia Arc generally referring to climate change impacts more than those for areas located on continental Antarctica. Despite rapid climate change having occurred over most of the Antarctic Peninsula, less than 6% of ASPA management plans detail how climate change has affected the management of the area. We recommend greater consideration of climate change within the Antarctic Protected Areas System and suggest designation of new protected areas to mitigate climate change impacts across the continent.

1342

Latin American theories in International Relations looks to Antarctica (and vice versa)

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The Antarctic Treaty System is dealing with several threats, such as the impacts of climate change, pollution, biopiracy, biological invasions, the increasing footprint of human activity, and the global power shifts. Within this context, it is worth reflecting on the contributions of the social science theories to the comprehension of such contemporary dilemmas for Antarctic policy-makers. Assuming that the production of knowledge is always situated, this paper explores Latin American theories in International Relations (IR) on Antarctica. The results show their view about the role that Latin America plays in the world politics, and concerning Antarctica, different views about the demands for the exploitation of resources, the question of the sovereignty, the future of the White Continent, and the Antarctic Treaty System. This paper concludes with some remarks about the contribution of such theories to the comprehension of the politics of Antarctica and highlights how these theories are elaborated in the context of new Antarctic dilemmas.

1430

'Logrolling' across Treaties of the Antarctic Treaty System: A Path to Pragmatic Compromise or Loss of Legitimacy in Antarctic Governance?

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The Antarctic Treaty System (ATS) is viewed as a successful example of international governance. This is due to the way the ATS has governed international tension over sovereignty claims and adapted to new issues, including marine resource management and environmental protection. However, over the last decade, two issues stand out as key geopolitical pressure points in Antarctic governance. First, in the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), several proposals to establish Marine Protected Areas (MPA) in the Southern Ocean have failed to achieve consensus. It is well known that China and Russia are key states who remain unconvinced of these proposals. Second, in the Antarctic Treaty Consultative Meeting, China has proposed special management arrangements for the area around the Kunlun research station located on the Dome A area of East Antarctica. Australia is one of several countries that remain unconvinced of the necessity for these special management arrangements. General theories of negotiation and international diplomacy suggests that 'logrolling' (i.e. issue linkage in negotiation) can be an effective strategy for states avoid gridlock and achieve joint gains from cooperation. This paper analyses the risks and opportunities for states in adopting a 'logrolling' strategy considering the above issues. We find that while logrolling may have the capacity to facilitate short-term diplomatic success, this would need to be weighed against a significant risk of weakening other rules and principles within the ATS, particularly in the context of a shifting global geopolitical order.

1495

The implementation of the Antarctic Treaty System by Latin American countries: a comparative case study

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Although the Antarctic Treaty System (ATS) is recognized as a good example of international cooperation, it is prone to interferences arising from member states' national interests. Historically, Latin American countries have been quite active within Antarctic Treaty Consultative Meetings (ATCMs), ATS' main decision making forum. Within these countries we can highlight Chile and Argentina, original members of the Antarctic Treaty who have requested territorial sovereignty in the region. Thus, based on the idea that each country's position on Antarctic issues results from the sum of domestic and international bureaucratic processes, combined with other forces (such as national geopolitical and economic interests), this study aims to answer the following question: do structural and political differences between Latin American Antarctic Programs influence the way their agents implement the norms established by the ATS? To approach this question we will observe the historical narrative about the construction of each country's Antarctic policy and national Antarctic program. We will also compare the characteristics of territorialist and nonterritorialist countries' programs. Methodologically, a comparative case study will be carried out using the process tracing technique, based on qualitative data collected from semi-structured interviews with key actors, official documents and relevant literature.

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Could climate change melt the foundations of the ATS?

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Participation as a consultative party to the Antarctic Treaty System (ATS) is largely dependent upon scientific activity – the "science criterion". In this paper I argue that the science criterion developed from a historically specific conception of Antarctica as a laboratory in which to study phenomena with both local and global significance, rooted in the International Geophysical Year (1957-58). But anthropogenic climate change has altered the continent's status from a somewhat abstract laboratory to a potentially existential threat to millions of people around the world. Should authority over Antarctica instead be invested in states most affected by physical geographical processes in Antarctica rather than the states that do most to investigate them? I conclude that the science criterion can remain viable, but that its legitimacy may be undermined unless a stronger case is made for the privileged association between science in Antarctica and positive outcomes for the world at large.

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Mapping conservation and rational use of the Southern Ocean: The CCAMLR system at a glance

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Different interpretations of the roles of conservation and rational use influence spatial uses of the Southern Ocean. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) has the primary (but not exclusive) responsibility for managing the activities that impact on marine life in the Southern Ocean, in accordance to the Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention). The objective of the CAMLR Convention is the conservation of marine living resources, including rational use subject to key principles of conservation that protect the ability of marine life to regenerate and thrive. A complex tapestry of Conservation Measures adopted by CCAMLR applies to different spatial and temporal scales, and for different fishing activities.Marine spatial protection is one of the tools used to achieve the Convention objectives. Non-spatial forms of management cover certain activities or practices as well as specific target species. The effectiveness of this system is influenced by the politics of CCAMLR and of the Antarctic Treaty System at large. Climate change and other stressors are an additional challenge to the longer term effectiveness of this regime. Based on the analysis of fishing and other records, in this presentation we map – both conceptually and in actual maps – the interaction between conservation and rational use in the Southern Ocean. Our purpose is to show how the CCAMLR system works at a glance, identify spatially defined conservation highs and lows, and make recommendations for improvement.

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Assessing National Antarctic Science Program: A Case Study of China

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China has become a significant and influential member of the Antarctic Treaty, following its accession to the treaty in 1983. China also met the requirements for consultative party status and China became an Antarctic Treaty Consultative Party (ATCP) in 1985. China has also acceded to other components of the Antarctic Treaty System: The Protocol on Environmental Protection in 1994 and the Convention on the Conservation of Antarctic Marine Living Resources in 2006. Although China's Antarctic activities started very late, its engagement as an active ATCP has attracted increasing attention. China's participation in Antarctic matters in general and Antarctic science, in particular, is of great significance. The primary objective of this paper is to analyse China's Antarctic science program and its engagement and participation in international cooperative science and evaluate its achievements. The paper examines, first, the requirements for China achieving consultative party status. It then examines China's performance as an ATCP through the history of China's activities in Antarctica and its commitment to logistics and infrastructure to support science in Antarctica. Finally, the paper examines the evolution of China's Antarctic science over the past four decades and considers key metrics to assess the quality and quantity of China's Antarctic science programs.

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SESSION 38

UNDERSTANDING 'THE ICE' THROUGH THE HUMANITIES, ARTS AND SOCIAL SCIENCES

Klaus Dodds, Charne Lavery, Elizabeth Leane

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Ice on Stage: Antarctica as Character, Theme, and Symbol in Theater

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How many places on Earth remain where there is a nearly empty stage? Is there any other place where that stage is solely inhospitable ice? Antarctica serves alternately, and often concurrently, as character, theme, and symbol, in dramatic pieces about Antarctica. As a genre, theater itself is the least productive and has the fewest pieces, in terms of literary texts set in or pertaining to Antarctica, in comparison to poetry and prose. This paper examines why: among reasons, the extremely limited performance opportunities in Antarctica itself; the exponentially growing interest in film over theater; and simply, fewer playwrights are interested in Antarctica. But, why should the theater and drama of Antarctica be of greater interest and increasing importance? Theater is the venue in which the spectators feel more involved and connected to the action; historically, the theory of the suspension of disbelief and the actor-spectator immediate communication, which is simply unavailable in poetry, prose, and film, gives the theater genre its unique ability to incite the audience to action, which, in the case of Antarctica, is becoming more critical. Several dramatic texts will be examined, including Tally’s "Terra Nova"; Moore’s "Passion for the Antarctic: A Short Play"; Brenton’s "Scott Of The Antarctic: Or, What God Didn't See"; Adebayo’s "Moj of the Antarctic"; and Young’s "Inexpressible Island"; for their use of Antarctica as character, theme, and symbol. These theater pieces have the potential to reach wider audiences, with the hope of growing increased awareness of, concern about, and passion for Antarctica.

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Unlocking the (News) Secrets of the Icy Continent: Journalistic representations of Antarctica in Australian News Media

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For most people, Antarctica is a mysterious frozen continent: home to heroic tales of daring adventure; a place dedicated to science and collaboration; and more recently, a symbol of fears about global warming. But who decides the terms of reference for the publics' understanding of the icy continent? The role of news media has been largely overlooked in Antarctic scholarship, which seeks to understand public engagement with the region. This is a significant gap in research, given the crucial role the news plays in shaping public opinion and its use as a tool by the 'power elite' to legitimise their policy decisions. In the setting of Antarctica and the Southern Ocean, the Australian news media's role in framing Australia's presence on the continent needs researching, as is the role these frames play in public debate and the subsequent development of policy impacting the region. Using the Australian news media as a case study, data collected from online news media outlets over a recent 12-month period will be analysed to identify prominent frames in news discourse about Antarctica. This presentation argues that exploring journalistic representations of Antarctica provides valuable insight into contemporary understanding of the icy continent, and helps construct ideas of power, control and ownership in Antarctica.

1465

Antarctica in contemporary visual art: more than a place of ice and snow

Adele Jackson[1]
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Stephen Pyne wrote convincingly that "Ice is the beginning of Antarctica and ice is its end”. This statement, first published in Pyne’s influential work 'The Ice' (1986) and quoted 4 years later in the opening contextual pages of the catalogue for Neelon Crawford’s 'Antarctica' exhibition, reflects commonly held imaginings and images of the continent. Yet, there are many more dimensions to this place which artists enable us to access.

Based on desk research and interviews with Antarctic researchers, artists, cultural professionals and the public as part of a study exploring the value of visual artists working in Antarctica, this paper discusses the diversity of concepts which have inspired artists’ inquiries. Concepts include spheres of life on earth; interconnection and interdependence; and questions of geopolitical and humanitarian significance. Taking this broader perspective of artists’ Antarctic inquiry creates space for deeper engagement and critical examination of the world in which we live.

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Visual artists' presence on the ice: a worrying picture?

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Visual artists working in Antarctica have informed and influenced human understandings and engagements with the continent since the earliest recorded expeditions, almost 250 years ago. Whilst white, Western men dominated the creation of Antarctic visual art for over 200 years until the mid 1980s, the 21st century heralded important advances. The cultural diversity of artists and the number of opportunities open to them increased dramatically. This diversified representation in the Antarctic visual arts canon and expanded the space for "other" voices within critical engagement with the ice. However, the closure of some programmes and more restrictive eligibility criteria for applications to those that remain has resulted in a severe decline in both numbers and cultural diversity.

This paper presents findings from an internationally focused study exploring the value of contemporary visual artists working in Antarctica. Analysis of 98 surveys, and 56 interviews with senior representatives of Antarctic organisations, Antarctic scientists and researchers, artists, cultural professionals, and the public reveals a consensus that artists' presence in Antarctica has positive value. Moreover, perceptions and descriptions of this value are wide-ranging and multidimensional with social, cultural, scientific, environmental and political significance. Whilst criticisms of artists' presence offer a counterbalance for consideration, their presence is frequently described as an essential and fundamentally important dimension of intellectual critical enquiry on the continent. These findings, when considered in conjunction with the decline in numbers and cultural diversity, support the conclusion that internationally more opportunities for artists need to be created and supported with long-term organisational commitment.

1049

Under the Ice: Literary Encounters with the Antarctic from Beneath

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Antarctica, The Ice, is vast, uniform, antithetical to most life. But this lifeless frozen crust belies a busy underneath: the sea plants which form hanging gardens on the underside of sea ice, the krill they feed, and the bustling—if seasonal—marine biological community the krill in turn support. The production of bottom water, retraction of grounding lines and operation of carbon sequestering are all critical Antarctic-submarine processes in a time of rising global temperatures. While the Arctic has a long history of submarine exploration, the subsurface Antarctic is less well-known. Against Cook's dismissive disappointment on glimpsing the ice cliffs for the first time, we might place the vivid sub-ice journeying of Jules Verne's explorers: bleak historical surface versus lively fictional depths.
This paper will explore fictional descriptions and visual representations of the Antarctic beneath the ice and water line, developing a perspective-from-below linked to the wider imagining of a southern submarine. It reads, for instance, South African science fiction author Lauren Beukes's short story, 'Her Seal Skin Coat', which develops interspecies collaborative exploration following seal scientist research, alongside Mohale Mashigo's 'Floating Rugs' which links polar whale migrations to the southern African coastline and conjoined postcolonial-ecological histories. Taking Christina Sharpe, Joshua Bennett and Fred Moten's work on blackness and the undersea further south and towards the ice, and in so doing exploring imaginative and political links between the unpeopled regions of the Antarctic and the deep ocean.

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The Empirical Sublime: Antarctic Ice, Time and the Poetry of Elizabeth Bradfield and Jean McNeil

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Antarctic ice is a materialisation of the movement of time on a sublime scale; as substance and symbol, it functions as a paradigm study for the impacts of climate change on the environment. In this paper, I would like to suggest that the Antarctic experience – transformative, paradoxical, increasingly bound up with empirical observations of the material world – requires an expansion of ideas about what kind of language is suitable to evoke the sublime, especially in the age of the Anthropocene. The sublime has a long history of association with writing about Antarctica, from the time when James Cook reached for the language associated with it to describe the qualities of the environment he was travelling through, to more recent writing about the continent which acknowledges its importance as an aesthetic category with evolving cultural, literary and environmental significance. Pursuing ideas of ice, the sublime and time, this paper will study representations of ice in the poetry of Jean McNeil and Elizabeth Bradfield, demonstrating that the concept of Antarctic ice brings together earlier traditions of the sublime in literature and landscape, with ideas about the sublime as it is implicated in climate change. Their poetry gives expression to an empirical sublime, full of measure and number, rooted in a sensory and intellectual interrogation of the material world, which, with its de-centring of a single human gaze, provides orientation (without grand gestures and dramatic sound effects) from within the vast, potentially overwhelming icescape in both its material and symbolic forms.

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Thinking from within and bewteen: ‘The Iceberg Project’ and the creative-critical approach.

Elizabeth Lewis Williams[1]
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Antarctica has become a paradigm study for the effects of human activity on the climate. Its ice acts as a living archive of earth’s climate history, and data collected as part of on-going scientific investigations measures current, and models future, changes. ‘The Iceberg Project’ offers poetry as an alternative method of interrogating some of that data. The poems present a variety of ways of seeing - remote imaging, microscopic scrutiny, poetic interpretation - and the sequence collapses both temporal and spatial scales in a poetic observatory located in an imagined Antarctica. Key to the sequence is a shaman, the animation of waste products, discarded plastic and creatures destroyed by a warming climate, gathered together by the reader through the poems which track a real iceberg, A68, from snowflake to calving, and a speculative one, towed by two tugboats, on its way to the UAE to provide water. This two-part oral presentation will involve a critical presentation followed by a short reading, making a case for the particular strengths of poetry to enable thinking from within a problem, moving between, and combining, different disciplines (poems include haibun on krill and diatoms). The complex positionality of the lyric voice (echoing the complex temporality of ice) enables “the conquering gaze” to be set aside, making the lyric, especially in sequence, an ideal form from within which to develop the kind of critical thinking which allows for a renewed understanding of the human position within the Anthropocene.

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Towards decolonial ways of thinking Antarctic Social Sciences and Humanities?

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Stephen J. Pyne in his book “The Ice. A journey to Antarctica” points out that ice structures in Antarctica present different variations in their form, shapes and movements. Such variations also happen in the diversity of knowledge production on the White Continent. Despite Antarctic Humanities and Social Sciences have grown in publications records over the last years, it is worth to have a look at the way it has been shaped. This paper explores the literature on Antarctic Social Sciences and Humanities published in English, Spanish and Portuguese. In doing so, we collected data from papers published in journals indexed in Scopus, Scielo and Latindex in the period 2013-2019. The results highlight the tendencies in the knowledge production and concerning Antarctica, focus on the main questions and major topics of interests, the funding institutions, the author affiliations of the most cited papers, the scientific collaborations networks, the types of knowledge circulation between countries and regions, and the perceptions about the future of Antarctica. This paper aims to promote discussions on decolonial and geopolitical approaches in the production of knowledge on the Antarctic Social Sciences and Humanities.

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Decolonizing Antarctica

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60 years after the General Assembly of the United Nations adopted the Declaration on the Granting of Independence to Colonial Countries and Peoples, the efforts made to decolonize occupied territories can be celebrated. Although 17 non-self-governing territories still remain, most of the former European colonies have gained independence. That decolonization is, as the Declaration asserts, an “irresistible and irreversible” process that has become part of the politically correct discourse. And yet, there is a whole continent where colonial claims are preserved “on ice”. In approaching the end of the Third Decade for the Eradication of Colonialism, Antarctica remains an enclave mostly run by the same colonial and wishing-to-be colonial powers that claimed whole wedges of it between 1908 and 1940, or reserved their rights to make a claim in the future under the auspices of the Antarctic Treaty (AT). While it has become a trope within the Antarctic humanities that the continent was and still is part and parcel of the colonial project, less has been said about what was morally wrong about it, and what decolonization of Antarctica would actually require. This presentation sketches an answer for these questions. First, it problematizes the appropriation by a few of vast expanses of “empty” space and suggests how this type of “white colonialism” risks being replicated in Antarctica and beyond. Second, it looks critically at specific elements of the AT, in particular Articles IV and VIII, and considers whether reforming them could be a first step towards actual Antarctic decolonization.

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On the edge: Towards an environmental and cultural history of Antarctic sea ice

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In this paper Joy examines the human and more-than-human histories of the sea ice that surrounds the Antarctic continent and islands. It represents the early stages of an environmental and cultural history of Antarctic sea ice that will explore the entangled histories of human and marine life at the edges of the Antarctic continent, as well as scientific and cultural engagements with the seasonal freeze and thaw of the circumpolar waters in the Anthropocene. This paper builds on Joy's recent work on Southern Ocean and Antarctic histories (Wild Sea: A History of the Southern Ocean, NewSouth 2018, UCP 2019; 'Australians and Antarctica: Stories From the Far South', National Library of Australia, in press; and, with Andrea Gaynor, '"I've had dolphins…looking for abalone for me": oral history and the subjectivities of marine engagement', Oral History Review, 44(2), May 2017). She will also discuss key themes and questions that frame her research, and consider the implications for environmental history, and the humanities and social sciences more generally, of studying the changing nature of human relationships with the dynamic, ephemeral, three-dimensional world of sea ice.

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'Instrumentalized Matter': Considering the use of Antarctic natural objects in Cheryl Leonard's musical works

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Cheryl Leonard is a San Francisco-based composer who over the past two decades has focused on investigating sounds, structures and objects from the natural world in her compositions, including in the set of ten pieces titled Antarctica: Music from the Ice (2009-14), inspired by her time spent as an artist with the US Antarctic Program. A key characteristic of Leonard's practice is that she cultivates natural objects such as water, ice, feathers, bones and shells – including from Antarctica – as bespoke musical instruments.

This paper considers how Leonard's creative practice problematizes and reframes the narrative agencies of Antarctic natural objects and processes. Using the theoretical lens of material ecocriticm, we will provide close readings of several of the musical works within Leonard's Antarctica, examining what new perspectives these works bring to contemporary understandings of human and more-than-human relationships with 'The Ice.'

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Icy Interiors: Materiality, Spatiality, and Atmospherics

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Antarctica and its ice mass are commonly described through spatial metaphors such as stage, archive, repository, cabinet, library, laboratory, window, portal, threshold, screen, curtain, mirror and sink. These notions related to interior spaces and elements are projected onto Antarctica as ways of understanding, imagining and conveying the continent. When the complex material conditions of the ice are taken into account, however, all of these interior metaphors are put into question. While this session aims to extend contemporary understandings of 'The Ice' through humanities, arts and social sciences, this paper applies Antarctica's ice critically to rethink the concept of the interior. Drawing on research in scientific fields of glaciology and atmospherics as well as the humanities, this paper takes a spatial approach to understand human interaction with the continent's ice and local climatic conditions, arguing for a form of thinking with the continent. Understood through its material variability and spatial complexity, ice is turned into a mode of enquiry to explore notions of 'insideness'. The spatial and interior metaphors projected onto the continent suggest distinct boundaries and contained sedentary fixed spaces. In contrast, a focus on the ice leads to a reconceptualization of the interior as conventionally understood. The ice is an organising force of unbounded interior conditions in ongoing flux. Antarctica is entangled with notions of the interior, albeit dynamically.

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How to convey Antarctic facts in South Africa with 11 official languages? Translate Antarctica to the previously disadvantaged in their home language.

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South Africa has been involved since the Heroic Age in Antarctica, but people of colour were only sent down to the three stations as part of the overwintering teams since 1989 (Marion Island) and 1998 (Antarctica). In the last decades, the demography of the teams has changed to represent all South Africans. The South African National Antarctic Programme has the responsibility to make Antarctica understandable for all South Africans in their home languages. Language forms the heart and soul of communication, traditions, social integration, and education. Language also plays a pivotal role in representing various cultures and traditions, as well as capturing the history of a community. The United Nations declared 2019 as the International Year of Indigenous Languages (IYIL2019). The South African Centre for Digital Language Resources (SADiLaR) is a national centre and at its core is the development of the South African languages, where they pool language resources and computational tools to ensure that our languages remain relevant in the digital age.

In collaboration with the Antarctic Legacy of South Africa (ALSA), SADiLaR translated general Antarctic Facts that were compiled in 2009, in all the official languages of South Africa. Workshops have been held by SADILAR and ALSA and translations of all 11 languages will be completed in 2020. This will be an ongoing project, as information will be revised and new information will be added. This presentation will highlight the process and the outcome of this collaboration during the IYIL2019.

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History from the freezer: early scientific observations of Antarctic ice

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Curating a recent Antarctic photo exhibition showing the diversity of work in the Antarctic it became clear that a majority of viewers were highly responsive to landscape pictures showing ice in its large variety. Photos shown were 'the' favourite personal pictures of a diverse group of University researchers who had travelled to the Antarctic. The viewers' choice of more than 200 submitted ballot papers revealed that pictures of icebergs fascinated most.
At the same time, many questions were asked about the history of early Antarctic exploration, the motivation of scientists, how findings were made, and the legacy of these findings. Paintings, photos, and descriptions of ice are available from early explorers who studied the ice. Many of them were geologists such as Hartley Ferrar (Scott expedition 1901–1903). His accounts on ice observations show a great passion and diversity in observation techniques. Otto Nordenskjöld, leader of the Swedish Antarctic Expedition (1901–1903) shaped the name 'ice shelf' based on his observations. David Paige, artist at Byrd's expedition 1933–1935, caught the icy world in stunning paintings.
This paper shows the exploration of Antarctic ice from a historical angle and focuses on early explorers' findings and their legacy that is still motivation and the basis of current research of a changing polar world. It will appear that ice has still its fascination until today and that the mystery of the icy world has been attracting both scientists and the public alike.

1706

On Blue Ice: Antarctic Meteorites and Deepening Planetary Time

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During the Antarctic field season of 1969, a group of Japanese glaciologists stumbled on a unique find—nine meteorite fragments, frozen and embedded in a patch of ancient blue ice. After geochemical analysis, the find was revealed to be even more surprising: rather than being pieces of one parent body, the meteorites were a collection of different rocks of varying terrestrial ages. An explanation lay within the ice: slowly spreading from the center of the continent, the Antarctic ice sheet was a “stranding surface” that collected, subsumed, and finally revealed meteorites over a vast timeframe. Since then, the Antarctic Search for Meteorites program (ANSMET) has scoured patches of blue ice for the rare celestial objects, collecting as many as 6000 unique fragments in one field season.

This paper takes up Antarctic meteorites as natural chronometers, and traces how the space rocks gave glaciologists and meteoriticists a unique temporal tool for understanding the shape and flow of the Antarctic ice sheet. It argues that by treating meteorites and ice as relational timekeepers, rendered legible through similar modes of geochemical analysis, geologists and astrophysicists repositioned blue ice as a scientific tool, one that could connect the deep time of Antarctic ice to the deeper time of the cosmos. In so doing, this paper repositions The Ice. While for Pyne, “Ice is the beginning of Antarctica, and ice is its end,” here ice is better understood as a complex and unique repository that connects Earth to the ends of the universe.

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SESSION 39

NEW APPROACHES TO ANTARCTIC AND SOUTHERN OCEAN HISTORIES

Peder Roberts
Joy McCann, Cornelia Lüdecke, Nelson Llanos, Andrew Avery

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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The diplomacy and geopolitics of 'environmental impact' in Antarctica, 1970–1991

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Since the signing of the Antarctic Treaty in 1959, the protection of the natural environment has become a central issue of Antarctic diplomacy and geopolitics. Environmental protection has been both a substantive concern as well as a geopolitical tool of inclusion and exclusion. This paper analyses the changing meaning and force of the idea of 'environmental impact' in Antarctic geopolitics during the 1970s and 1980s, when the original signatories of the Antarctic Treaty were exploring how to manage the exploitation of fisheries and minerals, as well as managing the interest of outsider states (from both the industrialised north and the decolonising and developing south) in Antarctica and its varied resources. This paper will explore three cases to explore the broader trend: the US Department of State's use of Environmental Impact Statements as part of its treaty negotiating process in the 1970s; the entry of China into Antarctic affairs and its siting of bases in Antarctica in the mid-1980s; and Greenpeace's expeditions to the region in the late 1980s. The paper aims to illuminate the many registers of the concept of 'impact' and how to assess and prevent it, including how current environmental management might enlarge or change its concepts of impact.

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Operational History and Analysis of United States Polar Icebreakers in the Antarctic 1956-2020

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The U.S. Coast Guard and U.S. Navy have operated polar icebreakers in support of United States national interests in Antarctica and the Southern Ocean for more than six decades. These relatively large icebreaking ships with high endurance have provided the United States with a visible and effective maritime presence in Antarctic coastal waters. In the early years they were critical to logistical support in the building of research stations at South Pole, McMurdo and Palmer on the Antarctic Peninsula; their icebreaking capabilities have been key to the annual ice escort operations of supply ships in McMurdo Sound; these sovereign state vessels have conducted with embarked State Department officials many of the U.S. Antarctic Treaty inspections including several voyages that were notable circumnavigations of the Continent; and, they have supported U.S. and international research expeditions and projects in waters that had rarely been previously explored. An analysis of this long-term operational history indicates the linkages of these multi-mission, national assets to geopolitics and U.S. influence in Antarctica. New U.S. Coast Guard polar icebreakers, now designated as polar security cutters, are being designed to operate at both ends of the world, whether breaking ice in the Ross Sea near McMurdo for resupply or for sustained operations throughout a more accessible Arctic Ocean. Theses new polar and naval vessels are the primary maritime law enforcement ships of the U.S. wherever they sail. This review will conclude with how such polar ships of all nations may be employed in uncertain Antarctic futures.

1649

‘Decolonizing’ Antarctica: Antarctic Humanities and Post-Colonial Discourse

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In various humanities fields, the idea of Decolonisation, or Decolonising Narratives is becoming more prominent, and ‘post-colonial’ approaches to research and historiographies are being deconstructed, and reconstructed as newer, ‘decolonial’ approaches.

Critical, ‘post-colonial’ approaches to Antarctica have been pioneered by Antarctic humanities scholars. The work of Adrian Howkins, Klaus Dodds, Peder Roberts, Lize-Marie van der Watt and many more has raised questions about the ways in which we have viewed Antarctica historically, and their work has shed light on new narratives in Antarctic history, critically examining the dominant, eurocentric historiographies of the continent. This presentation will argue that a decolonising approach must build on this work.

This presentation asks how the move towards decolonisation as a critical approach can feature in the ways we, as Antarctic Humanities scholars, can approach our studies. How do we bring a decolonising approach to a space which, it has been argued, was never colonised to begin with? And how does the history of the way Antarctica has been imagined affect the ways in which we can begin to construct a decolonial approach to Antarctic Humanities?

1659

Looking Antarctica from the Legal History: 177 years of Chilean rules over the Seventh Continent (History of the Chilean Antarctic Law 1843-2020)

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To fully understand the human relationship with Antarctica, the history about this connection must be covered from several points of view (i.e., discovery and exploration's history, scientific history, political history, and others). One of these approaches is Legal History. That is the evolution of the enactment and application of legal norms to the people, things and acts that are in the Seventh Continent or are related to it. In this sense, the international law about Antarctica (mainly the norms that conforms the Antarctic Treaty System) have been subject of several studies. It is a topic that deserves more research and analysis, but that is generally well known. However, the domestic law of several States about Antarctica is a less worked field. The National States can enact domestic law about Antarctica at least with two aims: First, to implement their Antarctic Treaty System derived obligations; second, in the case of the Claimants States, to demonstrate some level of sovereignty exercise. In the presentation, the case of Chilean domestic law will be analysed, covering more than 300 acts and regulations enacted at least from 1843 to nowadays. Will be discussed the different phases of this normative history, its general historical context, the main topics covered, the technical legal aspects of these norms, among other issues. The presentation is based on an academic work that is now being editing for its publication later this year.

1368

Transnationality as a method for studying the history of the Antarctic Treaty System

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Since decisions in the Antarctic Treaty System are taken in consensus, transnationality should be a self-evident methodological tool. All parties can potentially veto the decisions, thus the histories of the Antarctic Treaty that neglect any of the original signatories will inevitably be incomplete. Nevertheless, with a larger part of Antarctic humanities being either legal or institutional, the emphasis is still on the nation-states. Recently, transnational studies have been increasing, but even these are predominately using English-language materials, thus telling the story of the United States, United Kingdom, Australia and New Zealand. Japanese, Russian/Soviet, Argentinian and Chilean perspectives are mostly published in their national languages and are thus conspicuously missing from the history of the environmental protection of the Antarctic. I argue that transnationality is particularly suitable for environmental history and histories of modern technology and science as none of these objects of inquiry can be neatly enclosed into a national context. National histories set nation states as primary units of analysis, essentialising nations as separate monolithic entities, whereas transnational history can follow the flows of information and materiality between the countries, independently of the official position performed at the ATCM floor. A transnational history that goes beyond the brotherhood of the Commonwealth nations and includes more neutral observer countries would give a radically different version of some key events at the CRAMRA negotiations. At the same time, I argue that transnational history is more suitable than global history, since ATS never became a global institution that dominates over national agendas.

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Early Air – Sea-Ice Interaction in the Weddell Sea (1912)

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During the second German Antarctic expedition (1911-1912) Wilhelm Filchner planned to investigate whether east and west Antarctica were divided by a channel filled with ice or by land covered with an ice cap. Unexpectedly, Filchner's expedition ship "Deutschland" was trapped by ice and started a clockwise drift through the Weddell Sea in 1912, which was the one and only successful drift until today. Due to the new situation, oceanographer Wilhelm Brennecke continued to take soundings of the ocean depth. Besides the measurements of meteorological parameters, Erich Barkow started to investigate the upper air with captured balloon ascents up to more than 3000 m. Both scientists also included the observation of sea-ice while sailing south and during the drift in the later called Weddell Gyre. Even sea-ice temperatures were measured form the surface down to a depth of 50 cm. Finally the results were not published in a collective publication, because expedition members were completely disunited at the arrival in Grytviken (South Georgia). Barkow behaved neutral against the expedition leader Filchner while Brennecke was Filchner's main opponent. This situation prevented a collaboration in the evaluation of sea-ice observations, which might have led to the first publication of 11monthly air-sea-ice interaction in the Weddell Sea. The paper will show the limitations of data analysis at that time, when the polar front theory was not yet established and climatology of 10day, seasonal, and yearly mean values still prevailed in the early 1920s. However, the data were published and could still be analyzed today.

1443

Byrd's Life at the Pole: How Advertisements and Satire reveal the relationship between media, sponsorship and exploration in Antarctica

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This paper argues that the relationship between media, sponsorship and exploration in Antarctica can best be understood by engaging with both historical artifacts and lesser known resources such as contemporary fiction relating to the topic. Taking American aviator Admiral Richard Byrd's Antarctic expeditions as the starting point to discuss the development and commodification of the "hero business," the paper focuses on a 1935 booklet entitled The Romance of Antarctic Adventure. This booklet provides insights into how expedition sponsorship was translated back into domestic advertising, bringing Antarctica to life for a wide public back home whilst encouraging them to participate by consuming the same products back home. This historical booklet is analysed alongside a close reading of Wolcott Gibbs' satirical novel Bird Life at the Pole. This contemporary satirical response to the world of polar exploration offers a cutting commentary of Byrd's exploration practices, demonstrating that the close relationship between media, commerce and Antarctic exploration was recognised and incisively parodied by Byrd's peers. When revisiting past expeditions it is useful to consider a wide range of media artifacts as well as other forms of cultural production such as fictional texts. These add further depth to how the historical material available in archives can be understood, thus helping us to better understand the motivations behind and reception of early Antarctic expeditions.

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Creativity and organizational skills: a historical Italian approach to exploring Antarctica

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How does one organize the exploration of a hostile continent like Antarctica? Beyond the healthy madness that has always characterized exploration, Antarctica has presented a logistical and organizational challenge for all nations at the most advanced technological level. The Italian approach to Antarctica, on the contrary, was typical of the characteristics of Italian culture, which combines aspects of creative individualism with a high level of organization.
Following the example of other nations that raced to claim Antarctica at the end of the 1800s, Italy also attempted the expedition route but Lieutenant Giacomo Bove's project failed because the expense was too great.
The Italian conquest of Antarctica did not, in fact, take place until the 1960s. The years between 1968 and 1975 saw five expeditions; three government sponsored expeditions organized by CNR - CAI involving scientists and climbers, as well as two expeditions funded by private adventurers: Commander Ajmone Cat and Renato Cepparo (entrepreneur).
Commander Cat made the Antarctic crossing with a 16m felucca, making two expeditions (1969-71, 1973-74) crossing the Atlantic Ocean and the Drake Channel, reaching the Almirante Brown Antarctic base.
Renato Cepparo sold his film production company to finance the expedition and sailed from Lisbon on the Norwegian ship "Rig Mate"; in January 1976 he built a base camp on King George Island.
The two expeditions, the subject of intense media interest, raised awareness among the Italian political government, which later joined the Antarctic Treaty in 1981. The collections of these two expeditions are exhibited in our museum.

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Gender - does it really matter?

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Gender – does it really matter?

Headlines such as "…First black woman to reach both North Pole and South Pole"(1) or "50 years women in the Antarctic"(2) give the impression that we meet the target of acknowledging the achievements of female pioneers in the Antarctic. It also shows that the history of women and indigenous people seems still a short one. Indigenous people, black men, black women, white women in the Antarctic – does gender matter? The answer lies already in the questions itself because we still make these inquiries.
Concerning women, however, there are strong voices supporting women in the Antarctic as L.N. Bernacchi and F. Debenham did bearing the idea of bringing women to the southern continent from the start. In some cases, indigenous women worked as sealers until a change of law made this illegal. Women were also an important factor back home although their history is often overlooked.
The gender and race question is still highly discussed even when there are some achievements, but there is still more to do to satisfy the demand for proper gender history. This paper will introduce some historic cases where women and indigenous people made their footprint on the white continent but have been often overlooked or were only presented as an example of good will.

(1) https://www.nytimes.com/2019/11/26/us/barbara-hillary-dead.html?smid=tw-nytimes&smtyp=cur
(2) https://twitter.com/hashtag/WomenInAntarctica?src=hashtag_click

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What can historians of Antarctica learn from historians of the Arctic?

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This paper argues that historians of the Antarctic can learn three lessons from historical studies of the Arctic. The first concerns exceptionalism. The unique nature of the Antarctic Treaty and the continent's geographic remoteness, have reified its exceptionality with regard to the natural and social characteristics that dominate the rest of the world. Histories of the Arctic have by contrast emphasized connections and gradated difference, borne out in the late Louis-Edmond Hamelin's index of nordicity. The second concerns a more nuanced appreciation of the political value of science. While it is essentially impossible to write about the history of modern science the Arctic without the Cold War and its dynamics as integral to the nature of such research, we contend that histories of modern Antarctic research can be too quick to separate science from the political contexts in which its support made sense. Finally, we argue that histories of environmental management in the Arctic have often been more nuanced than those in the Antarctic due to greater appreciation for the historical context in which animal introductions, natural resource harvesting, and even pollution regulations made sense. We conclude that increased dialogue between historians of the Arctic and the Antarctic, and indeed historians of all kinds, can help to produce new and perhaps more revealing histories of human activity in Antarctica.

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Wilkes Subglacial Basin: From a White Spot on the Map to Global Tipping Point

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Wilkes Subglacial Basin (WSB) is located inland from the inaccessible George V Coast in East Antarctica. The lack of outcrops and topographic features limits the sense of place for humans. In the past, WSB has only attracted minor interest of exploration parties and limited research focus. The area has remained a white spot on the Antarctic map.
New insight puts a spotlight on WSB and drastically changes our perception of this large geographical area. WSB is identified as one of the most important and irreversible tipping points in global climate models. Since International Polar Year 2007–2008, a number of studies have pointed out the immense volume of ice, and the potential instability of the ice sheet due to the low topography and rising ocean temperatures. Wilkes Subglacial Basin (and similarly e.g. the Thwaites Glacier, Totten Glacier, Aurora Subglacial Basin) already appear in daily news reports, and in the future, we might see media articles about the subglacial topography with the same precision and familiarity as when war journalism brings distant mountains, valleys, and deserts onto colorized and animated maps in television news and tabloids.
We record the early transition of WSB from an abstract obscurity to its emerging recognition and importance for humanity. We review known and documented visits, names of subglacial features and early mentions in media.

1407

A new approach to the history of the first successful rescue in Antarctica in November 1903 and its implications in the international context

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This work was elaborated in the context of celebrating 200 years of Antarctic exploration and research, being an artistic transposition of the November 1903 event that has remained in history as the first successful rescue in Antarctica. An Education&Outreach project through Romanian-Argentine cooperation was initiated in this regard. Thus, two of a painting series on the theme "Argentine Corvette Uruguay saving in 1903 the shipwrecked Swedish expedition to Antarctica", evoking the rescue on Snow Hills (8.11.1903) and Paulet (10.11.1903) Islands, were achieved as a tribute. They were exhibited in Buenos Aires on the museum Uruguay Corvette on February 22, 2020 on Argentine Antarctic Day, 116 years after the establishment of Orcadas Station - the first Argentine Antarctic base to be the oldest stable human presence on the continent. This painting series continues with the rescue on Seymour Island (7.11.1903). The painting design involved careful documentation using the volume "Antarctic Challenges. Historical and Current Perspectives on Otto Nordenskjöld's Antarctic Expedition 1901-1903", offered by Sweden at the Antarctic Treaty Consultative Meeting, Stockholm 2005, and sources available on the Internet, but also archival documents provided by the Argentine party. The paintings are accompanied by an extensive documentary paper on international implications and benefits of both the Argentine rescue mission and the Swedish Antarctic Expedition through its scientific results. The project is a symbol of deep appreciation for the President of the Argentine Antarctic Academy, Comodoro de Marina Marcelo Tarapow, and of other Argentine officials who supported us in the Antarctic activities of Romania.

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VALUES IN ANTARCTICA: IDENTIFICATION AND VULNERABILITY TO ANTHROPOGENIC IMPACTS

Rupert Summerson, Kevin Hughes
Shaun Brooks

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Antarctic geological heritage: identification, vulnerability and threats

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Antarctica is a key piece to reconstruct the Earth's geological history. The Antarctic territory contains information that in some cases is unique, a model particularly representative of certain geological aspects, or is among the best examples in the world. Therefore, some Antarctic geological (including geomorphological) features can be considered as part of the geological heritage of international relevance at a global scale. To identify such elements is currently an object of attention by the Antarctic scientific community, and advances in that direction are taking place through the SCAR Action Group on Geological Heritage and Geoconservation. A necessary first and basic step to be taken before considering any possible subsequent conservation actions is the identification of the elements that form part of geological heritage, which needs to be based on the scientific consideration of their intrinsic value and following the appropriate systematic methodology. Once destroyed, geological elements cannot be recovered or restored. Hence, geological heritage must be managed considering also an assessment of its fragility, vulnerability to threats, and risk of degradation. While some geological elements are spectacular and evident, others may have great scientific value even though they may go unnoticed by a non-expert, so their destruction may occur due to ignorance of their value. This work presents a series of concepts and procedures to detect the susceptibility to degradation, vulnerability and quantification of anthropic threats, which should guide potential protection measures for those elements of the Antarctic geological heritage that require it.

1146

Defining the environmental footprints of McMurdo and Palmer Stations, Antarctica

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The term “footprint” is commonly used in Antarctic environmental research. Only recently, however, has the term received a systematic examination aimed at developing a common understanding of its meaning. Additionally, the first continent-wide estimate of buildings and ground disturbance has recently been made. This recent work provides an ideal framework for synthesizing over 15 years of environmental monitoring observations made at McMurdo Station and for a shorter period at Palmer Station. These two station represent a wide range of station sizes found on the continent – from a mid-size peninsular station to the largest human occupancy on the continent. Geographic Information Systems (GIS) analysis provides quantitative estimates of the spatial extent of multiple overlapping footprints (geochemical, building, ground disturbance) at these two stations that adhere to the newly established “footprint” definitions. After delineation of individual “footprints” (e.g., total petroleum hydrocarbons or buildings) a systematic analysis of their overlap is undertaken. Typically, areas heavily impacted by human activities at both stations are found to occur within multiple “footprints.” Standard GIS overlay operations may provide a straightforward means of producing a hierarchical assessment of impact for a station and its environs. As accurate estimates of two footprints (buildings and ground disturbance) exist for both stations from their construction until present, temporal trends in the early growth, and their subsequent relative stability, of these two “footprints” will be described.

1148

Mapping the marine spatial footprint of U.S. science and operations on the Antarctic Peninsula

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Recently, attempts have been made to define the term "footprint" as it applies to the human impact on the Antarctic terrestrial environment. While some research has investigated the spatial footprint of ship-based Antarctic tourism, little work has examined the spatial footprint of marine science. The ASRV Laurence M. Gould (LMG) has been the primary support vessel for United States Antarctic Program (USAP) operations on the Peninsula since 1998. Thus, its location maps the spatial footprint of US science and operations. Navigation files recording the LMG's position were used to construct an overall picture of its time in Antarctic waters. Positions from 209 cruise tracks representing approximately 77% of the ship's total cruises and a higher percentage of its cruises within the Antarctic Treaty waters were binned into 5x5 km areas in western Antarctica. More detailed observations from a smaller number of cruises (approx. 200) that included a timestamp for each geographic location mapped the LMG's spatial footprint seasonally and over the period of record. Clear patterns emerge, such as the annual Palmer Long-Term Ecological Research Program summer sampling cruise. Other areas of concentrated activity related to specific activities such as scientific fishing are also evident. This demonstrates that basic geographic information such as the position of a research vessel can provide useful information documenting the footprint of specific scientific activities on the Antarctic Continent.

1210

Study on the status quo and proposal of Implementing Spatial Planning in Fildes Region, Antarctica

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The Antarctic is one of the most primitive and vulnerable ecosystem in the world. In view of the intensification of global climate change and the increase of polar human activities, the Antarctic and its ecosystem are facing unprecedented changes. The continuing concern of the international community to mitigate and adapt to these changes has prompted an ongoing call for an ecosystem-based approach to manage human activities in the Antarctic. In many sea areas around the world, marine spatial planning has become an effective way to transform this concept into management practice, which could be a new tool for the comprehensive management of polar oceans. The Fildes peninsula is characterized by high density of scientific research stations, abundant human activities and rich biodiversity. It is an ideal research area for spatial planning studies. By arranging the important bio-ecological distribution and human activity space information in the Fildes Peninsula regions, the zoning system for spatial planning was constructed. Three first-level functional zones were set up: important biological protection zones, human activity functional zones and Antarctic characteristic protection zones. There are ten second-level functional zones: integrated demonstration zone of biogeographic protection, typical species protection zone, fishery operation zone, scientific investigation zone, Antarctic tourist zone, flight/shipping channel zone, maritime search and rescue zone, historical relics zone, aesthetic value zone, and wilderness value zone. Research on spatial planning in the Fildes Peninsula regions can effectively protect marine biodiversity and ecosystem functional integrity, reduce and resolve spatial conflicts between current and future human activities and nature.

656

The Environmental Protocol and Climate Change: A Problem of "Fit"?

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The concept of "regime fit" is used in environmental governance to measure whether a given institutional arrangement is adequate for dealing with its subject matter. For example, the fact that an organization like the Convention for the Conservation of Living Marine Resources (CCAMLR) uses an ecosystem approach to decide fishing quotas could be seen as fitting for its purpose—if the aim is to keep fishing practices in the Southern Ocean sustainable. The "problem of fit", accordingly, arises when an institutional arrangement is insufficient or inadequate for dealing with its subject matter. This is arguably the case, I claim, with the Environmental Protocol of the Antarctic Treaty. While highly restrictive regarding the activities that might be conducted in the continent, the Protocol does not protect Antarctica and its nonhuman inhabitants from their biggest threat, i.e. rapid climate change. What it would require to make the Antarctic regime "fitting" is the question for which I then offer a preliminary answer.

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Ecosystem services in terrestrial Antarctica: on the quantification of unmeasurable values

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Ecosystem services describe the many benefits provided by healthy functioning ecosystems, including food provision, climate regulation and recreational benefits. An assessment and understanding of ecosystem services has directed effective conservation and/or management in many areas across the globe. Policymakers are starting to embrace ecosystem services studies that focus on the Southern Ocean, but equivalent studies for Antarctic terrestrial environments are still largely absent. Here we present a first screening of ecosystem services in terrestrial Antarctica, with all socioecological features provided from the conservation of Antarctica under the Antarctic Treaty (AT), particularly attending to the inclusion of indirect, non-monetary bequest values. Ecosystem services assessment frameworks provide robust and widely applicable mapping tools to assist with the long-term sustainable decision-making adopted by the AT parties. Moreover, these evaluations offer a valuable framework to integrate the region into global assessments and conservation planning agendas.
Pertierra LR & Hughes KA (2019) Antarctic Science, 31, 229-230.

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Thresholds of wilderness

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The Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol), requires the protection of the wilderness and aesthetic values of Antarctica (Article 3). There has however been little progress in protecting these values (Summerson & Tin, 2019).
Previous research (Summerson & Bishop, 2011) has postulated that, given the hostile nature of the Antarctic environment and lack of permanent settlement, all of Antarctica should be considered wilderness except for those areas that have been degraded by human activity. It is proposed that the principle form of degradation is the construction of infrastructure (e.g. stations) which is perceived by its visibility. This begs the question whether there is a distance threshold at which an item of infrastructure is no longer perceived as having an impact on wilderness? Or is the threshold complete invisibility or absence?
A research project designed to answer this question has not been logistically possible which has meant using existing data. An Internet survey on perceptions of wilderness using three sets of 30 images of Antarctic landscapes, 50% of which include a variety of types of human presence and distances (Summerson 2013), has provided over 13,000 responses. This dataset has been analysed with a random forest using the Knime Analytics Platform to attempt the prediction of non-wilderness from the combination of intensity of human presence and distance. Preliminary results indicate that for complex infrastructure visibility is the most important factor in determining perception of non-wilderness with distance a less important factor.

1370

Protection of the intrinsic value of Antarctica - a way forward

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The Madrid Protocol requires the protection of the intrinsic value of Antarctica (Article 3) but to date there has been little understanding or substantive debate about what intrinsic value means or how its protection can be effected.
The Action Group on Intrinsic Value in Antarctica (AGIVA) was formed under the auspices of the SCAR Standing Committee on the Humanities and Social Sciences to develop and promote a better understanding of the concept of intrinsic value across multiple cultures and to model a framework for implementing the duty towards intrinsic value enshrined in the Madrid Protocol.
In this paper we outline a framework rooted in the field of philosophy from which the concept of intrinsic value was derived, namely Ethics. An ethical framework is widely applied in biological and social sciences for any project involving the use of humans and animals. Practitioners in these fields are well accustomed to responding to questions related to ethics in project proposals and grant applications, which are generally considered by formally constituted ethics committees. We propose a similar framework for all research and operations proposals in which proposed activities would be considered for their potential impacts on the intrinsic value of the environment. These would then be formally balanced against the benefits argued for the proposed activities. Whilst this may already be done partially via EIA, the ethics of the proposed activities have hitherto not been considered. We propose a number of indicators to close this gap and assist the process.

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LIVING AND WORKING IN ANTARCTICA

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Daniela Liggett, Gabriela Roldan

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Finding a 'sense of place' upon the white expanse of ever moving ice at the end of the world

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Antarctica is a place with no Indigenous peoples, a place with no real human story. It is a kind of frontier of impermanence. It is not a place to plant roots, or raise a family. It is a place of short contractual work, research, and experimentation. It is a place in which our survival is utterly dependent upon the structures we have built. It is not a place to make a home nor a place to live out your full experience as a human being. It is a frozen and melting land mass beneath the southern lights at the end of the world. It is a haven for wildlife trying still to escape the effects of our kind. It is an iced over dessert that attracts displaced inquiring minds in human form for months at a time. It is a place so remote, cold, white, and hostile, that our very mortality is always in question. It is in this very mortal relationship we share with this place, that forges our identity, and dictates our way of life. Ours therefore ought not be a question about living and working in Antarctica, as much as it is a question of "being" in Antarctica. How am I to be in Antarctica?

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Perception of harassment in expeditionaries of the Brazilian Antarctic Program

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Introduction: Harassment is a psychosocial risk characterized as a recurrent and intimidating behavior that is usually harmful. The topic became prominent in public discussions regarding polar environments in 2018, especially after notorious accusations, and gaining force due to the #Metoo movement. Objective: to investigate the experiences of perceived harassment in expeditioners of the Brazilian Antarctic Program (PROANTAR). Methods: a pilot study utilizing an online questionnaire with PROANTAR expeditionaries (n = 16), to improve a risk management protocol in Antarctica. Results: Four participants, all-female, reported having suffered harassment. Eight participants witnessed or heard about fellow victims of moral and sexual harassment. Of these, only five reported what happened. Fear of reprisals from their superiors was the main reason for not reporting the cases. Ten people (seven women and three men) agreed that women are more at risk of harassment than men. Ten people agreed it is possible for men to be harassed, and two disagreed. Conclusion: Where there are human interactions there is a risk of harassment, whether in a polar (confined and isolated) environment or not. It is important to raise awareness about harassment and to encourage reporting, reducing both inaccurate definitions or perceptions of interactions and victims' fear of exposing this type of violence. PROANTAR's actions to support sensitive research aimed at the safety of its expeditionaries must be acknowledged. Respondents considered the research important and its continuity is necessary for a better understanding of the issue and consequent harassment prevention.

The New Zealand International Geophysical Year (IGY) program and the start of the NZ Antarctic Research Programme.

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New Zealand (NZ) scientists contributed to the objectives of the 1957-58 International Geophysical Year (IGY), by expanding the range of regular meteorological and geophysical measurements at its existing observatories (e.g. New Zealand, Campbell Island, Samoa) and setting up several new observatories that extended to 78° S (Scott Base) in the south and to 0.1° N (Tarawa in Kiribati) in the north. The proposed research program was carried out largely by existing government research agencies using partially redirected resources with some additional funding to support the expanded programme of geophysical research. It was coordinated by an interdepartmental government committee under Dr E Robertson. A comprehensive programme of research was developed for Antarctica involving a new base in the Ross Sea region. At the same time the government agreed to support in part, the Ross Sea Support Party for the UK based Commonwealth Trans Antarctic Expedition (TAE). The new joint base, Scott Base, was set up in McMurdo Sound, for both the IGY party of five scientists and the TAE Ross Sea Support Party. In addition, three NZ scientists undertook the IGY geophysical research programme at Hallett Bay – a joint US/NZ base on the western Ross Sea coast. For the second part of IGY (March to December 1958), Scott Base was run by the NZ government and an expanded research programme and new scientific coordinating committee developed – the start of the New Zealand Antarctic Research Programme.

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Research For The Turkish Antarctic Research Station (TARS)

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Research For The Turkish Antarctic Research Station (TARS)
*Yuksel Demir
*Architect, Assoc. Prof. Dr., Coordinator of TARS Working Group in ITU Polar Research Center (Polrec), Faculty at the Department of Architecture, Istanbul Technical University, Istanbul, Turkey,
This paper summarizes the initial phases of the research done for the establishment of The Turkish Antarctic Research Station (TARS)
The most important part of the research process is precedent analysis, in which each base is examined in detail. Within the frame of the criteria determined, 31 bases were first selected and a database containing basic data about these bases was created.
In addition to the database, a short report has been written for each base in the database. In the data collection process, besides basic resources such as COMNAP and ATCM, data obtained as a result of one-to-one interviews with the designers of the bases and national Antarctic Program managers of the countries, and the feedbacks of Turkish researchers from various bases during TAE I and TAE II expeditions were used. Since the Spring semesters of the 2018-2019 academic year, research by design studies was conducted and continues in undergraduate and graduate project studios. In doing so, the findings obtained in the preliminary research, different design strategies, program, and design suggestions were developed. We did also contact potential stakeholders. It is planned to establish a platform that includes stakeholders from all disciplines (including artists, philosophers, and intellectuals) in order to share and facilitate the development stages (Research -Design -Development) of the base.

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The New Brazilian Antarctic Station Comandante Ferraz: prospects for the antarctic constructions technological innovations

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After the first geological-geotechnical studies carried out by the Brazilian Navy in the Antarctic summer 2014, the construction work began for the new Brazilian Antarctic Station. This civil work was designed for the research development in several areas of knowledge, such as geosciences, engineering, biology, chemistry and medicine.
The construction was completed in 2020 and has 4,500 square meters of built area, including 17 laboratories for Antarctic research. The Station has an energy cogeneration system, comprising diesel generators integrated with renewable wind and solar energy modes.
Adverse environmental conditions, such as winds up to 200km/h, soils subject to freezing and thawing cycles, the occurrence of ice sheets in the subsoil, as well as earthquakes, have made the construction in Antarctica an engineering challenge. Thus, both in the design phase and construction, the foundation soil geotechnical characteristics and the site environmental conditions were observed, in order, for the technical adjustments to ensure the safety building condition.
The construction process experience and the sensors implantation for monitoring the soil and the Station structure will be the subsidy for the new construction technologies development in Antarctica, including a laboratory for the soil and foundations behavior studies under the Antarctic environmental conditions.

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Penguin Priests and Glacial Gods: Religion and Spirituality in Antarctica

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In literature of Antarctica, one religious theme appears the most frequently: death. Death is always nearby, in the crevasse of a glacier or swirling in a blizzard. Although most corpses lay buried where the person died, there are three cemeteries on Antarctica, as well as places of worship. The first aspect of this paper is dedicated to these spaces, from the few actual churches built in Antarctica, to rooms in research stations where religious services are held. Linked closely to the actual "architecture" of religion are the accompanying musical and artistic components of spirituality. In several texts about Antarctica, such as explorers' journals, polar parties sing hymns and carry images of God. Similarly, the use of prayer appears in many pieces of Antarctic literature. Nearly everyone who has traveled to or lived on Antarctica has remarked about being awestruck upon seeing Antarctica for the first time, and those who openly spoke of being agnostic or atheist, admitted to their beliefs being tested, for numerous reasons: the unbelievable beauty, the majestic natural magnificence, surviving incredibly harsh weather, or somehow escaping certain death. This paper illuminates a spiritual aspect about Antarctica: unlike a mirror, the ice of Antarctica reflects a shattered image, like that of a broken heart, and perhaps that is the pull to Antarctica. Being in Antarctica might give those who are paralyzed by grief a small taste of heaven, because it is so remote, so beautiful, and so peaceful. Truly, Antarctica might be where mourning dawns and hope arises.

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What do people new to Antarctica and the sub-Antarctic need to know about the weather and environment? Advice from people living and working in Antarctica and the sub-Antarctic.

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Antarctica is an extreme and isolated environment where cold exposure can lead to injury, diminished cognitive capacity, decision errors, and even death. Understanding, awareness, and knowledge of the environment may reduce risk and improve human safety, performance and resilience in Antarctica. Information may be passed to new expeditioners through the mentoring, tips, and stories of experienced expeditioners. We were interested in what the people who have lived and worked there thought it was important for 'new' people to know, learn, and remember about Antarctica's surprising, changeable, and potentially deadly weather and environment. Essentially, we were interested in what we can learn from people who live and work in these extreme environments.
As a part of an exploratory study of weather information use and decision-making in the Antarctic and Sub-Antarctic we interviewed 30 people who were currently or recently deployed there. Interviews were conducted via video and audio calling, email and in person. Participants included people who were very experienced in their roles with multiple years and trips to those who had only one season of experience. Here we examine participants thoughts on severe weather and risk in Antarctica, and their answers to the question: "What does someone new to Antarctica and the sub-Antarctic need to know about the weather and environment?"
We discuss recommendations and advice people might give to a new colleague in Antarctica and the sub-Antarctic, and how this information can be used to guide training and enhance performance for those working in these environments.

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Weather information sources, decisions, and needs: Insights from an online survey exploring how, when and why people use weather information in the Antarctic and sub-Antarctic.

Victoria Heinrich[1,2], Kimberley Norris[1]
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Weather affects everyone in Antarctica, dictating work, travel, and research schedules. Adverse weather can risk lives, impede research projects and prohibit outdoor activities which can have catastrophic impacts on organisations involved in polar work. Additionally, there is limited literature on weather information use and decision-making in Antarctica. As such, understanding people's weather information use is important to improving weather services, human safety, and performance in these regions.
Using an online survey, we collected information on the types and sources of weather information used by people recently deployed to Antarctica and the sub-Antarctic and how this influenced decision-making. Participants were from National Antarctic Programs, tourism operators, and private organisations with Antarctic experience ranging from a single deployment to multiple trips over the last 20+ years. Participants included tour guides, tradespeople, pilots, scientists, forecasters, and managers.
Results indicated that weather information was used to plan and schedule activities, minimise risk, and maintain safety. Planning decisions and choice of weather information source were context and task specific. People often discussed weather decisions with weather professionals, operations mangers, field support, captains, colleagues, and supervisors. There were similarities in people’s weather-related decision-making and information use despite variations in their locations and roles. Wind speed and direction along with short-term forecasts were perceived as the most useful weather information to guide decision-making. Access to forecasters was deemed extremely valuable for weather decision-making. Results of the current study demonstrate that weather information and weather-related decisions are an important part of participants Antarctic functioning and ability to work.

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Emergence of Antarctic Biomimicry: potential for an interdisciplinary approach to building design

Katelyn Hudson[1]
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Antarctic architectural expression has evolved from pure, basic shelter, to space-age capsules that crawl around the ice. Though separation and buffer from the natural environment have remained. Not only for basic survival that the extreme climate requires but from familiar building and design practices. The direction that station design has progressed opens the door for other approaches that discover how other aspects of that natural environment have existed in Antarctica. Biomimicry is a design practice that was identified by the scientist Janine Benyus in the mid-1990s; endeavouring to study and learn from strategies employed in nature and how they can be incorporated to solve problems. It built upon the biomimetic work of Otto Schmitt and is included in Stephen Kellert's biophilic design attributes. Applications range from design, materials, optics, systems, etc., but this research focuses on the potential for architectural design. To date, there has been no completed architectural intervention that has used biomimicry in Antarctica. Investigating two published conceptual works from 2014; the snowflake greenhouse of the Venice Biennale and the student project: Transformable Antarctic Research Facility (iceberg), there is room for an interdisciplinary approach to biomimicry in future station design that goes beyond an aesthetical shell. Entailing interdisciplinary work of architects and engineers together with the scientists to learn from their research to study environmental, floral, and fauna adaptations that could merge into building design. This is a logical potential trajectory of the future of Antarctic Architecture.

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Biophilic Design in Antarctica: connecting to nature through architecture

Katelyn Hudson[1]
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Humans developed the built environment through a series of behavioural patterns interacted with natural aspects necessary to provide shelter and protection from their surroundings. These practices have continued to innately be utilised and identified as 'biophilic design'. This research investigates how those elements have been utilised in one of the few climates where it is particularly pertinent, requiring humans to still rely on buildings purely for the basic purpose of survival, Antarctica. Through a case study framework, six examples of buildings ranging the history of human habitation in Antarctica will be explored; Robert F. Scott's Hut at Cape Evans, Douglas Mawson's Hut, Australia's Casey Station, United Kingdom's Halley VI, and the United States of America's McMurdo Station and Amundsen-Scott South Pole Station. Not only do they represent significant periods in the relatively short Antarctic history, but they illustrate different scales, building practices, material technology, cultural backgrounds, and location within the continent. The cases will be then analysed based on the elements and attributes of biophilic design to investigate how it has been integrated. The result of this research gains greater insight into biophilic design regarding residential architecture, as well as tracking building practices concerning occupant well-being.

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Does a specific “space culture” develop on the ISS?

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Researchers interested in the workplace have long studied corporate cultures and their variants in other environments. There is general agreement that workplaces have individual characteristics, norms as to interpersonal behavior, dress codes, acceptable and unacceptable modes of communication, and so on. With regard to long-duration spaceflight, such topics have typically been addressed indirectly, by examining interviews, reminiscences, and other evidence that the researcher could use to infer what the crew experienced as unique and shared, and which social scientists could interpret as cultural. The current study, involving 13 astronauts (NASA and other agencies), took a more direct route by administering questionnaires to the participants at various stages of their service from training through spaceflight and after returning to Earth. Questions asked whether the participant identified the existence of a specific space culture, its features, its importance as compared to the culture of national origin and sponsoring space agency, and the norms of those different cultures followed by the astronaut as a function of circumstances. This report presents the data from two on-orbit questionnaires. For comparison, similar questions were asked of Arctic personnel at remote stations.

723

The Graveyard Shift: An Investigation into the Peculiar Case of Deception Island.

Elizabeth Lewis Williams[1]
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The Base Journal for the British base on Deception Island 1953-4 opens with a death. The fact that it is a suicide is not recorded. Two days later, after landing stores and coal, and stripping the No 1. engine, the men start digging a grave in the frozen ground of the old whaling cemetery. It takes three days. Five years on, the General Report and Base Journal for Deception begins with a note that this year had probably been the happiest in the history of the base, and that the island should no longer be considered one of the worst postings for members of the Falkland Islands Dependency Service.
With particular reference to early Base and Field reports, as well as to letters and memoirs held in the British Antarctic Survey archives, this paper will examine what gave rise to such a negative view of Deception Island. The psychological report from Halley Bay in 1959, which comments on the difficulties of life on a static base, particularly over winter, when "one had to adapt oneself to circumstances or perish", suggests that some of the difficulties experienced on Deception were common elsewhere. Comparing the rough notes of two recovered diaries from Deception to official reports from the same years, this paper will highlight the psychological pressures of winter darkness, and the various means by which the men were able to combat it, attempting to answer in the process whether or not there was indeed a peculiar case of Deception Island.

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The Ministry of Food: the practical, psychological and symbolic importance of food as evidenced in early British Antarctic Base and Field Reports.

Elizabeth Lewis Williams[1]

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In Antarctica, where everything required for a person's survival has to be imported, all aspects of food take on a significance over and above its necessity for keeping people alive. With particular reference to the Base and Field reports from the early years of the permanent British Antarctic research stations, this paper will explore the significance of food, showing that its preparation and shared consumption was important not just for feeding the body, but psychologically and symbolically: for maintaining individual morale and developing team spirit; for providing occasion for moving out of gender roles at a time when British bases were all male communities; for building a sense of home in an alien environment. Looking back at this period and beyond, we can also see from writing about food the apparent collapse of the material and the abstract, the real and the imagined, which is one of the characteristic aspects of the Antarctic experience as it is presented in writing. Birds, for example, provided a source both of companionship and fresh meat, as well as a different means of reading the environment; rituals surrounding the celebration of particular occasions, often with a very limited range of things to eat, were one of the ways in which food figured not just as something eaten but as part of an imaginary construct. A study of food, and attitudes towards it, has much to tell us therefore about what motivated the men who worked in Antarctica, their sense of values, belonging and identity.

1036

Creating 360° footage of South Africa's Antarctic and sub-Antarctic research stations; SANAE IV

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The Antarctic Legacy of South Africa (ALSA) is a Knowledge Development Grant project within the South African National Antarctic Programme (SANAP). Its aim is to facilitate knowledge building about the work and life at the three stations of South Africa on Antarctica, Marion Island and Gough Island. ALSA was granted the opportunity to visit SA's Antarctic Station in January 2019 during the take-over period, tasked to gather 360° footage of the SANAE IV station. The SANAE IV base can now be viewed through a 360 tour available on the SANAP website.

This material will play a big role in the preparation of future overwintering personnel, as they will now be able to familiarise themselves with the station and get a sense of how it will be to live in the confined space of the station. It will also give family and friends of team members and take-over personnel the opportunity to understand their loved one's new environment. This new addition, the 360° station exploration, to the Antarctic Programme was released on International Antarctica Day 2019, on the brand new upgrade of the SANAP website.

This presentation will give insight into the process of creating this material in a short time span. The process and difficulties in getting the footage will be discussed, as well as the most effective way to make this knowledge open accessible.

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Working as researchers in the challenging research field of human biology and physiology

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The most isolated and extreme continent of the world offers a unique opportunity to investigate several aspects of human physiology, psychology and sociology in this environment that includes research ships, research stations, shelters and remote research camping's. However, in comparison to the major fields of scientific research covered in most Antarctic Programs the research in human biology, human physiology and medicine is under-represented. This is a very challenging field of Antarctica work. Diversely of other researchers studying the air, the water, the ice, and the earth in its many aspects, the human biologist investigates the military personnel, the staff in the Research Stations and Ships, and the scientists that work in Antarctica. Several specificities in this kind of research demand extensive planning, logistic details and adaptation of operational schedules impacting the quality and quantity of data collection and implicating the outcome of scientific publications. The human biology approach needs to consider ethical aspects, the limitation of human and technical resources and equipment restrictions to be transported. Most research in this field depend on voluntary recruitment and usually demand long-term follow up, including pre and post examinations of the subjects, which are difficult considering the composition of the research groups of civilian and military voluntaries, with their diverse geographical origins in Brazil and other countries. We expect to bring our experience, perspectives, and our motivation in order to facilitate the discussion about the socio-cultural dimensions of working in Antarctica as while researchers in the human biology field.

1413

A clinical audit of knee and ankle injuries on Macquarie Island 2000-2014

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Ingrid McGaughey and Peter Sullivan investigated the epidemiology of knee and ankle injuries on Macquarie Island in 2001. Over the period examined in the first paper from September 1990 - August 2000 13% of medical consultations were knee and ankle injuries. The new clinical audit has reviewed the subsequent period from September 2000 to March 2014. Despite the prevention program instituted by the Polar Medicine Unit since the McGaughey and Sullivan findings, knee and ankle injuries continue to represent 12.1% of recorded consultations on Macquarie Island.

Macquarie Island is a sub Antarctic Island with a rugged and unforgiving terrain and this level of injury is not unexpected. The preventative measures introduced since 2001 have not significantly reduced the number of injuries. Department of Primary Industries, Parks, Water and Environment, Tasmania (DPIPWE) screened their Macquarie Island Pest Eradication Program (MIPEP) employees before deployment which also did not reduce injuries during the MIPEP. It may be that screening before departure or preventative measures cannot overcome the dangers and risks posed by Macquarie Island.

442

Traversing Antarctica: Inhabitation on the Move

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Due to the relative inaccessibility of Antarctica, the small number of studies that investigate inhabitation from cultural, historical and geopolitical perspectives are centred on interpretative and/or archival research. Limited research comprises remote fieldwork and embodied encounters with the extreme environment.

This paper focusses on the inhabitation and the interior conditions of the French IPEV logistical traverse that resupplies the French Italian Concordia station. The traverse is explored as a spatial practice and a distinct mode of inhabitation through an autoethnographic investigation. This study of the traverse offers an alternative understanding to the sedentary Antarctic stations and provides an engagement with the environment different to that of regular scientific traverses. As participant observer on the IPEV traverse RAID63, I developed first-hand and experiential knowledge of inhabiting Antarctica. This study – through an embodied engagement with the technical, social and natural extreme environment – is located at the intersection of the Antarctic humanities and interior design theory.

This exploration into the traverse extends existing understandings of Antarctic inhabitation. The turbulent environment operates as an organising and forceful agent in the production of interior conditions. My investigation reveals a glacial mode of inhabitation; one that replaces a sedentary way of living for a living/moving with the ice. On the traverse, inhabitation and the notion of the interior must be constantly reinvented in the accelerations and decelerations determined by Antarctic forces. Balance, rest and comfort – traditional assumptions of the interior – can only be found within the movements of these external forces.

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Antarctica in Black; Expression of Feelings of Antarctica through Art.

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South Africa has sent overwintering teams since 1948 to their stations in the Antarctic region. There is also a takeover period during which conservation and construction personnel and scientists visit these stations for work. Most of the people that work in Antarctica have the tendency to capture these experiences in photographs diaries and videos. However, there is a few that express their feelings and emotions in sketches and paintings. Jess Verheul,, a scientist and an emerging artist expressed this through sketches in ink - hence the name “Antinktica”. During a Research Expedition to Antarctica (the South African National Antarctic Programme – SANAP) she spent some of her spare time sketching while watching the world around her. She state in her book “Armed with a few fineliners, a blank sketchbook and a boatload of time, I set out to observe and experience the place of my dreams even deeper. To remember. To feel. To wonder. To appreciate it all the more”. She initially had no plans to publish her art. Since the opportunity was presented by the Archivist at the Antarctic Legacy of South Africa (ALSA) to publish it in a coffee table book and the book launch took place in March 2020. The book consists of 49 sketches; including 3 poems depicting scenes experienced by Jess during her Antarctic Expedition. Only 100 publications are available. This poster will give an insight to Jess’s experience and show some of the sketches.

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Mental Health In The Antarctic Confinement: A Monitoring Model

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The aim of the present study is to develop a model for monitoring the mental health of personnel stationed in Antarctic. Initial in loco data collection provided researchers with an important insight on living conditions and activities developed at each location. It lasted a period of eight weeks during the summer months. Information collected from civilian and military personnel was obtained using interviews, focus groups and self-administered questionnaires. Data is being analysed using a sociocultural perspective. Thus, compensating for the limitations arising from physical extremes and isolation, the exceptional opportunity of coexistence of researchers with a significant portion of the population focus of this study, consisting of individuals of different characteristics which, equally, are subjected to very different conditions of everyday life, allows confirming and generalizing hypotheses in relation to mental health and to seek to standardize more effective longitudinal monitoring system compared to current ones, in general based on mental disorders. Thus, in intersubjective contexts, in which social mediation by means of signs plays a crucial role, it is possible to study the psychic phenomenon in occurrence and recognize underlying processes resulting from the tension and struggle between the biological and the social, which we call the axis of Submission and Resistance, in which human action, on a case-by-case basis, is subjected to parameters of forced coexistence, strict rules, strenuous routines, restricted possibility of coming and going, and will be weighted by explicit resistance mechanisms and hidden responses that are reflected in a spectrum of psychophysiological and behavioral responses.

1718

Are Space and Polar Stations Really Analogous? A Comparison of Some Psychological Measures

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Although polar, and especially Antarctic, stations have long been considered analogues of long-duration space habitats, there is a growing body of literature examining that assumption. The implication is that data from one of the two ICEs are generally predictive of what would be found if the study were replicated in that other. However, there are myriad differences between the single space station and polar stations, as well as among the many polar stations themselves that vary considerably in size, architecture, amenities, population, tasks, external and internal environment, etc. We have recently suggested that one way to test the analogy is to administer the same psychological tests in both settings. The current paper reports one result of this suggestion.
A current study of crews on the International Space Station includes the administration of measures of experienced stress, ways of coping, basic values, and personal changes in the individual from the time of training to post-return to the Earth. The results of this study will be compared with other measures of the same variables administered to crews in Antarctic and Arctic stations, as well as other space environments.

1412

“HABIT-ANT?” Is housing in Antarctica equivalent to inhabiting the place ?

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"HABIT-ANT?" is a scientific and citizens' initiative whose mission is to explore the interactions between humans and non-humans in a changing world in the particular context of the Southern and Antarctic zone. To do so, the global common model of Antarctica becomes a living laboratory that goes beyond the geographical location by involving people who are not there but are connected to the Southern and/or Antarctica. The link can be sensitive, poetic, scientific, managerial or any other type. The project is to design space-time that encourage the emergence of collective intelligence and serendipity. The project thus invites observation, dialogue and reflexive approach with tools from Environmental Sciences, Human and Social Sciences, artistic practice as well as Participatory Action Research in a world in metamorphosis.

The first part of this study consists in conducting an analysis of anthropized and protected sites such as the Kerguelen archipelago, the Crozet archipelago, the Amsterdam and Saint-Paul islands and Terre Adélie, through the prism of habitat. Occupied by man to house essentially "observatories" (scientific as well as political), these places are also home to an Antarctic culture, creating a contemporary heritage. It will be complemented by workshops conducted in remote sites to explore legacy, perceptions and representations associated with the Southern and Antarctica.

745

Validating a sustainable Antarctic station design and as-built: A New Zealand custom sustainability accreditation tool.

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The New Zealand Antarctic Programme is currently designing a new Antarctic station, as the current station, Scott Base, has reached the end of its life. The Scott Base Redevelopment Project will be the largest construction project ever undertaken by New Zealand in Antarctica.
To demonstrate leadership in sustainability throughout the design and build process, a sustainability accreditation program that is both robust and specific for the Antarctic built environment was developed in collaboration with the New Zealand Green Building Council. A bespoke custom tool for a “Green Star” design and as-built accreditation scheme was the result.
The custom Green Star tool encourages practices that reduce the projects contribution to climate change, enhance the health and wellbeing of inhabitants, ensure high performance of buildings, and contribute to sustainable market transformation. The tool requires this project to reduce its embedded and operational environmental impact. Methods such as the implementation of Life Cycle Assessments (LCA) and greenhouse gas modelling with iterative improvements are incorporated in the tool.
To achieve accreditation, sustainable elements, environmental performance, and innovative solutions are incorporated into a station’s design. Sustainable elements and the delivery of Green Star are also included throughout the main contractor procurement process.
This presentation will delve into the development of this custom tool, strategies and opportunities Antarctica New Zealand have developed to minimise its impact from the construction of a new station, and some preliminary results from an LCA model. The potential for collaborative development of Antarctic sustainable rating systems and LCAs will be discussed.

1251

Turkish Polar Expedition behavioral evaluation program

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Humans are highly adabtable to various conditions, but there are still questions that need to be worked through concerning effects of extreme climate conditions on human psychology. We developed an internet-based computer program for the psychological evaluation of the polar expeditioners and for the purpose of developing a training program for future expeditions. This information-support package will consist of psychosocial support videos with information on coping strategies, group interaction, team leadership, problem solving skills, impulse control skills and relaxation exercises based on experience from international studies and previous National Antarctic Science Expeditions participants. Data will be evaluated by 3 psychiatrists and 3 experienced polar scientists to gain an understanding for possible future conflicts that could interfare with future expedition work or well being of the group members. With the help of this knowledge, we are planning to improve our program to help researchers be better prepared for the expedition and to improve the safety and training program of the group. We are also planning to improve the program with human supervised machine learning which will be supported by bigger data sets from different groups such as high mountain climbers, and other groups working in extreme environments.

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1260

Logistics challenges of living and working in Antarctica

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Polar regions needs to be well known to better understand our future in every aspects. To reach and study those places, a well organized logistics strongly needed. Many countries had been working for many years with many experiences in the continent. With the developed technology and speed of reaching informations worldwide, make the expeditions safer and better planned. The consequences of expeditions which made by nations, were well examined to clearly understand logistic needs of polar expeditions before planning our own. Turkey had completed four successful Antarctic Scientific Expeditions (TAE) and established a research camp to operate between 2019-2022.
Turkish Scientific Research Camp had three modules which has laboratories, kitchen, living space and depot. The camp operates during summer seasons during our Antarctic campaign. We charter a vessel approximately for 30 – 35 days from Chile. The cargo of the expedition is also delivered to Punta Arenas. The vessel capacity with two helicopters, zodiac boats and barge is usually quite effective to carry on all logistic needs to the study area and the camp site. This study will indicate the challenges and coordination during the logistic activities of both scientists and general needs of living and working in Antarctica.

1247

Behavioral Evaluation of the Turkish Antarctic Expedition – IV Participants

Cenan Hepdurgun[2], Hayriye Elbi[2], Ozgun Ozalay[2], Seren Kirmizi[3], Sinan Yirmibesoglu[1,4], Ozgun Oktar[1,4], Burcu Ozsoy[1,4], Sebnem Pirildar[2]

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Polar expeditioners often face various psychological challenges due to difficult environmental conditions, isolation and confinement. There are also positive psychological effects of participating in polar expeditions by means of coping successfully with stress, increased self-esteem and progress in personal development. Certain characteristics such as low susceptibility to anxiety and high motivation to achieve have been reported to be associated with better adjustment to short term expeditions. Therefore, identifying behavioral characteristics of the participants before the expeditions would be beneficial for developing prevention and intervention strategies prior to departure.

In addition to personal interviews held by two psychiatrists, we have evaluated 17 participants of the Turkish Antarctic Expedition – IV via the Temperament and Character Inventory, the Beck's Depression Inventory, the State – Trait Anxiety Inventory, the Resilience Scale for Adults and the Profile of Mood States. As expected, scores regarding anxiety and mood disturbances were below clinically significant levels for all of the participants. The mean scores of the Self-Directedness and the Cooperativeness subscales were significantly high while the mean score of the Harm Avoidance subscale was significantly low in Temperament and Character Inventory. A behavioral training program consisting of informative videos was prepared for participants considering group characteristics. Continuing behavioral and psychological evaluation for the further polar expeditions may help developing more personalized supportive strategies for expeditioners.

This Research is supported by Scientific and Technological Research Council of Turkey (TUBITAK) (Project no:219S316)

SCAR 2020

Antarctic Science -
Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 42

LESSONS FROM THE POLES: REMOTE LIVING, WORKING AND HEALTHCARE IN THE POLES, AND ANTARCTICA AS THE ULTIMATE SPACE ANALOGUE

Anne Hicks
Mark Shepanek, Nathalie Pattyn

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Development of a Masters Program for Healthcare in Remote and Extreme Environments at the University of Tasmania

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This presentation describes the development of the Masters program in Healthcare in Remote and Extreme Environments. It emphasises the collaborative approach used with industry partners, notably the Australian Antarctic Division and outlines the curriculum development process to cater for a diverse range of professional roles in different extreme environments.

The philosophy and educational approaches are discussed, and in particular the innovative content relevant to Antarctic, Space and Extreme Sports Medicine is explored.

The presentation will conclude by looking into the future and determining the ongoing direction of the program.

1590

Women's Health in Extreme Environments

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BACKGROUND
Austere, low-resource environments on land, underwater, and in space pose unique healthcare challenges. Some health risks impact women differently than men. To date, many of these differences are understudied; only a small fraction of expeditioners to extreme environments such as Antarctica and Space have been female.

REMOTE MEDICAL SYSTEMS CONSIDER GENDER DIFFERENCES

Terrestrial Extreme Environments
Behavioral health stresses of isolated, confined, and extreme (ICE) environments such as Antarctica appear to affect women and men differently. Lack of sun exposure, dietary constraints, and decreased weightbearing in winter environments results in bone loss, but exercise was shown to preserve bone and lean mass in women trekkers in Antarctica. Women are at higher risk for UTIs than men. Oral contraceptive use is associated with increased risk of DVT. Cardiovascular (CV) disease in women is severely understudied, but gender-specific care is needed to reduce morbidity and mortality.

Spaceflight Environment
Fluid shifts are problematic in microgravity resulting in physiologic responses such as ocular changes (only symptomatic in men to date) and concerning vascular flow abnormalities. DVT has been documented in mission but risk factors need further delineation. Adaptations to microgravity include muscle atrophy and bone loss which occur differently in women than men.

SUMMARY
Women’s health in austere environments is understudied, partly owing to overall low numbers of female polar explorers and only 11% of astronauts worldwide being female. Fortunately, female involvement in Antarctic and Space expeditions is increasing, allowing for needed gender-specific physiologic research across both environments where certain parallel risks exist.

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Tearing Along the Continent:
The Challenges of Evacuating an Aortic Dissection From Antarctica

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Introduction:
The challenge of Antarctic medicine comes from the pairing of an extreme and hostile environment with lengthy extraction timelines, and a need to provide prolonged medical care in clinical austerity. There are direct parallels between delivering care in Antarctica and delivering care in another operational environment – prolonged spaceflight.

Case Description:
The presentation of an aortic dissection late into the Austral summer encountered a number of these challenges. With limited investigations, there was initial diagnostic uncertainty despite thorough history taking and clinical examination. Disease progression was detected by serial examinations, which allowed a conclusive diagnosis to be made. Initial transportation was by ship to another nation's Antarctic base for aeromedical evacuation. The patient was flown to a tertiary hospital for definitive treatment and has since made a full recovery. This case also demonstrates the limitations of pre-deployment screening and potential for significant unexpected diagnoses.

Discussion:
Caring for critically unwell patients with limited resources often relies on the support of non-medical team members such as the first aid party. Managing their skills, expectations, and working hours can be difficult especially when risk of patient death is high. Confidentiality is a concern in confined environments, and is challenging when dealing with multiple stakeholders. Clear communication between all parties including the use of telemedicine proved essential in co-ordinating patient care. These challenges are likely to be replicated in prolonged spaceflight and may be mitigated by using the experience of Antarctic clinicians to guide planning and training.

1215

Antarctica; the proving ground for Space Medicine

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The launch of the Australian Space Agency provides an opportunity to promote and grow Australia's space assets. One key asset is the Australian Antarctic Division's Polar Medicine Unit (PMU) which has been supporting significant advancements in the field of Space Medicine for years.

The PMU has been a key contributor to the development of new medical training guidelines for the European Space Agency's (ESA's) Astronaut Corps. These guidelines are designed to train non-physician astronauts in the medical skills required for spaceflight; this training is now mandatory for all ESA astronauts prior to spaceflight. These guidelines were directly informed by the experience of the PMU and other partner organisations in undertaking the emergency medical management of patients in an Antarctic setting.

As international space agencies look to the Moon and to Mars, they are faced with unique medical challenges that must be overcome if astronauts are to safely operate within these environments. Antarctica is a well-established space analogue environment with a proven history of managing medical emergencies that are translatable to space flight. The experience of Antarctic nations can be utilised to inform the future of Space Medicine, ensuring crews are optimally trained and prepared for exploration and habitation missions.

As Australia steps onto the world stage with the launch of the Australian Space Agency, we have the potential to learn from our Antarctic experiences and contribute to the next great step in exploration and scientific endeavour.

1271

Challenged by extraordinary Exposomes: lessons learned on neurophysiologic and immunologic changes and its impact on space flight, polar expeditions and health on Earth

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The humans´ adaptation skills to changing environments have been critical to be an explorer and to survive extreme environments on Earth. These frontiers are pushed further and after 50 years after landing on the moon and establishing a permanently base orbiting Earth (ISS), he is striving to new dimensions of (deep)space exploration and permanent outpost.

In Antarctica and in space the exposome comprises conditions that the crew are exposed to during their stay in these extreme environments and to which they have to adapt to in order to maintain physical and mental health. Antarctica is challenging humans with some stressors similar to space. The impact of the space-exposome, as recently shown, includes neuro-structural impairments and immune pathologies. The impact of each of the potential causal factors for these changes remain under debate and microgravity, but as well as the isolation conditions are among the most important factors. Accordingly, brain imaging in polar expeditioners before and after wintering-over at the Neumayer station showed that the volume of the hippocampal dentate gyrus was reduced and expands results of morphological changes seen as a consequence of isolation mimicking long duration space flight. Moreover, immune dysfunctional states seen in overwintering crews show interesting similarities to observations when challenged to the space-exposome.

This ground work in Antarctica is of unique translational value for crews in the extremes and for patient as all have to cope to different extent with prolonged confinement, social and environmental deprivation and its effects on the brain and the immune system.

1276

Sleep Quality Changes during Overwintering at the German Antarctic Stations Neumayer II and III: The Gender Factor

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Purpose:
Antarctic residence holds many challenges to human physiology, like increased psychosocial tension and altered circadian rhythm. We assessed changes in sleep patterns during 13 months of overwintering at the German Stations Neumayer II and III from 2008 to 2014, with focus on gender.
Materials & Methods
Time in bed, sleep time, sleep efficiency, number of arousals, sleep latency, sleep onset, sleep offset, and physical activity level were determined during seven overwintering campaigns of n = 54 participants (37 male, 17 female) using actimetry.
Results:
We found overall longer times in bed ($p = 0.004$) and sleep time ($p = 0.014$) for women. Gender had a significant influence on sleep time ($p<0.001$), number of arousals ($p = 0.04$), and sleep onset ($p<0.001$). Physical activity decreased over overwintering time for men ($p = 0.003$), but not for women ($p = 0.174$). The decline in sunshine radiation led to 48 minutes longer time in bed ($p<0.001$), 3.8% lower sleep efficiency ($p<0.001$), delay of 32 minutes sleep onset ($p<0.001$), and 11% less daily energy expenditure ($p<0.001$), for all participants during the darkness phase.
Conclusions:
Overwinterings at the Stations Neumayer II and III are associated with significant changes in sleep patterns, with dependences from overwintering time and local sunshine radiation. Gender appears to be an influence, as women showed a declining sleep quality, despite that their physical activity remained unchanged, suggesting other causes such as a higher susceptibility to psycho-social stress and changes in environmental circadian rhythm during
long-term isolation in Antarctica.

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Physiological Changes in Participants of an Ultramarathon in Subarctic Climate – the Yukon Arctic Ultra

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Purpose:
The objective of this study was to determine alterations in energy expenditure, body composition, metabolites, and cytokines in athletes participating in the Yukon Arctic Ultra.
Materials & Methods
Ten participants (8 males, 2 females; age: 37 ± 10 years) traveling on foot in the 2017 692-km event were recruited for the study. Measurements and samples were obtained at pre-event, 278 km, 384 km, and post-event (692 km). Outdoor temperatures ranged from +5 to -47°C. Body composition measurements were obtained using bioelectrical impedance analysis. Accelerometer devices provided an estimation of caloric expenditure and dietary recalls gave assessments of caloric intake. Blood serum samples were collected, and analyzed using enzyme-linked immunosorbent assays or nuclear magnetic resonance.
Results:
Four males and one female completed the entire event in 260 ± 19 h. Caloric intake was 4,126 ± 1,115 kcal/day and expenditure 6,387 ± 781 kcal/day, indicating a caloric deficit of 2,261 ± 1,543 kcal/day. Total mass, body mass index, and fat mass were reduced at each time point of the event. Fat-free mass (FFM) was unchanged throughout the event. Follistatin was increased at C1 (1,715 ± 876 pg/ml) in comparison to baseline. Acetoacetate increased significantly at post-event (6.1 ± 1.5 mg/ml).
Conclusions:
Despite a pronounced caloric deficit and sustained activity under extreme cold conditions, FFM was preserved with an increase in serum follistatin, indicating preservation of musculature, and acetoacetate, indicating increased fat-metabolism. Future studies should be directed at the role of nutrient strategies for retention of FFM under these conditions.

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CHOICE-e kick-off: Monitoring occurrence of hypersensitivity reactions in (Ant-)arctic environments

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In previous studies in Antarctica significant hypersensitivity and immunological changes have been quantified ex vivo. These observations complement case-reports from overwinters and findings by NASA on ISS-crewmembers, where the occurrence of newly developed allergic type reactions is increased, in relation to isolated and stressful living conditions. Based on those findings, the CHOICE-e (e=epidemiology) study has been initiated in 2019 to survey the epidemiology of such reactions at Polar stations. Data will be collected systematically via a simple web-/ app-based survey prior to-, during and post their polar (overwinter-) expeditions about occurrence of such allergic incidences.

Once they sign up, CHOICE-e volunteers first undergo a personal interview and a general questionnaire evaluating each individual´s predisposition for a broad range of sensitivity/allergic reactions. During and after the respective missions, CHOICE-e volunteers are tasked with filling out a shorter questionnaire about the possible occurrence of allergic reactions and self-estimating stress scores. For over-winter 2020, CHOICE-e has 109 volunteers, enrolled at 12 stations (2 arctic/10 Antarctic) from 7 polar institutes.

Systematic data on incidence of sensitivity reactions after exposition to extreme, isolated and confined conditions will be a result of CHOICE-e, expected results will be helpful to develop mitigation and countermeasures to prevent immune dysfunctions in extreme environments, with potential applications for daily lives.

Due to the complementary ground and space-based nature of the research, CHOICE-e is uniquely conducted under the umbrella of the European Polar Board(EPB) with support from the European Space Agency(ESA)

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Methodological challenges in psychological researches and practices in Antarctica

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Introduction: The Antarctic Isolated, Confined and Extreme Environment (ICE) is considered a natural laboratory for the study of human physiology and behavior. However, the same contextual characteristics imposes limitations on conducting on-site research. Objective: to map the methodological challenges in researches and practices in the field of psychology conducted in the Antarctic environment. Method: Participative observations were made on the spot onboard ships, Air Force planes and at the Comandante Ferraz Antarctic Station (2014-2019) with expeditioners from the Brazilian Antarctic Program. Results: The main challenges identified include weather conditions (which require quick decision making without prejudice to the methodological and ethical aspects of the research), complex setting in Antarctica (reduced guarantee of privacy and continuity of psychological practices), interruptions and unforeseen events (which impair control of variables), empirical studies still emerging (making it difficult to choose appropriate instruments and techniques), reduced number of participants (which does not allow for more robust statistical procedures) and the researcher's immersion requirement (sharing residence and workspace 24 hours a day, which can impair the necessary distance between the researcher and research object). Conclusion: Interdisciplinarity, especially with anthropological methods, was important to complement the work of researchers in the field of Psychology, allowing a broader look at the phenomena investigated, in the face of challenges. Working in such a context requires tolerance to frustrations and creativity to reallocate the research method with viable alternatives predicted. Remote access technologies can present themselves as effective tools for planning and carrying out studies in psychology in the future.

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Medical research in Japanese Antarctic research activities: a review of the current status and future prospects

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The Japanese Antarctic research activities initiated in 1956 reached the 61st expedition in December 2019. The total number of the Japanese Antarctic Research Expedition (JARE) members who participated exceeded 1900. Medical staff managed the health of the members and also engaged in medical research. Although the participants of the research were few, the findings were greatly valuable.
In this review, a detailed search of original articles was performed using the PubMed-MEDLINE database to identify recent English literature and the Ichushi-Web (Japan Medical Abstract Society) database to identify Japanese literature relevant to Antarctic medicine. We also confirmed the records of the National Institute of Polar Research.
A search on PubMed for “Antarctic, Japan, human,” found 16 original papers in English since 1994. An article on disease and injury statistics related to the JARE was published in 2004 and updated in 2019. There were two topics related to immunity. Eight were related to closed environmental sleep and circadian rhythm, while one was about resident bacteria of the skin, seasickness, bone metabolism, and urination.
A search on Ichushi-Web for “Antarctica, Medicine (in Japanese),” found 62 original papers (54 in Japanese, 8 in English), 6 commentaries, and 94 conference proceedings in Japanese since 1959. The most frequently discussed was a review of Antarctic medicine, followed by physiological adaptation, psychology, and sleep/circadian rhythms.
According to records from the National Institute of Polar Research, since 2014, one review of psychological research (in Japanese, with English abstract) and one publication of IntechOpen have been published in English.

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Vitamin D Supplementation: lessons learnt from Antarctica

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Bone loss occurs during prolonged sunlight deprivation leading to vitamin D deficiency. We observed amongst healthy adult expeditioners to Antarctica, an annual reduction of 1% in femoral neck bone mineral density during an expedition, and vitamin D deficiency (25(OH)D <50nmol/L) within 4 months of deployment. Our subsequent randomized double-blind placebo-controlled vitamin D supplementation trial indicated that a 50,000IU dose of vitamin D every 2 months maintained vitamin D adequacy (>50nmol/L) with a monthly dose required to improve levels if <50nmol/L. Subsequently a policy statement and vitamin D supplementation protocol was developed in 2009 and implemented for the Australian Antarctic Division to ensure vitamin D adequacy in all wintering expeditioners in Australia's Antarctic Program. Since implementation of the Vitamin D supplementation protocol we have recorded serum vitamin D levels at the end of Austral summer prior to entering winter isolation, and on return to Australia to assess the effectiveness of this protocol. Vitamin D supplementation dosages and serum 25(OH)D levels prior to, and at the end of isolation will be presented to determine clinical efficacy of this evidence-based protocol. Further work including assessing safety concerns such as risk of renal calculi will support the establishment of a standardised evidenced-based approach to vitamin D supplementation across the Antarctic expeditioner community, to help ensure skeletal health is maintained in all expeditioners. Efficacy of evidenced-based Vitamin D supplementation, compliance, and risks in Antarctic isolated confined extreme environments informs health and well-being planning for Antarctic and other sunlight deprived populations on Earth and in space.

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How do wintering members use their experience in prior missions to Antarctica? – The possibility of psychoeducation about stress before a mission.

Nanako Kato[1], Tetsuya Kawabe[2], Nobuo Naruiwa[3], Asako Sasaki[4], Tomoko Kuwabara[5], Giichiro Ono[6], Kentaro Watanabe[7], Satoshi Imura[7]

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[Purpose] Japanese wintering members are placed enclosed and isolated in Antarctica and need to maintain their mental health by relying on themselves. It is necessary to provide information about stress before a mission, however, inappropriate information may directly be associated with serious risks related to enclosed environments. Thus, it is critical to select useful information for maintaining the mental health of wintering members in Antarctica. On the other hand, there are experienced members who have acquired knowledge of stress based on their prior wintering mission. Therefore, this study aims to investigate how experienced members use their previous experiences for the next mission. The main purpose is to generate clear and useful information to be used before a mission based on this research.
[Method] 1) Results obtained in the Profile of Mood States(POMS) were compared between the experienced and first-time group. 2) Qualitative analysis of post-mission interviews with seven experienced members was performed.
[Results]1) In the third quarter of the mission, the experienced members had discrepancies in their mood. 2) Experienced members also had to endure dual viewpoints regarding themselves and the entire group during this period.
[Conclusions] Information of periods during which members have diverse variations in their mood is more important than individual mood change. These results also suggest that providing knowledge before a mission regarding individual variations is valuable.

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Psychological characteristics of the third-quarter phenomenon investigated by Baum test

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The third-quarter phenomenon is a cluster of symptoms consisting of sleep disturbance, impaired cognition, negative affect, and interpersonal tension and conflict experienced by people on polar expeditions in the Antarctic after the midpoint of an expedition, with some reduction in symptoms toward the end (Palinkas and Suedfeld, 2008). Our previous research has shown that the negative affect associated with the third-quarter phenomenon comprises anger and hostility (Kawabe et al., 2014), that the phenomenon occurs regardless of job type or personality (Kawabe et al., 2016), and that members of polar expeditions often do not consult with a medical doctor when they suffer from the phenomenon (Kawabe et al., 2018). In this study, we administered a tree-drawing test (Baum test), which is a projective test used extensively in psychology, to 28 members of the Japanese Antarctic Research Expedition (JARE). On the basis of the results, we investigated the psychological characteristics of the third-quarter phenomenon through case studies on nine persons who exhibited the third-quarter phenomenon. We uncovered three negative psychological states: 1) temporary collapse of psychological balance, 2) a certain amount of ego inflation, and 3) increased aggression, along with three positive ones: 4) self-awareness of one’s conflicts, 5) having confidence to refuse, and 6) having the will to solve problems. These results demonstrate that the third-quarter phenomenon has two-sided characteristics, both positive and negative.

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Thermal insulating clothing promotes increase in forehead sweat efficiency during an Antarctic expedition

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From a physiological perspective Antarctica has a very challenging environment since the cold and wind are stressful stimuli for the human body. Thus, it is necessary the utilization of appropriate clothes that would create a microenvironment to avoid significant drop in body temperature. Due to its thermal insulating characteristic, the heat exchange with the environment may be impaired by those clothes, and during Antarctic displacements may lead to an accumulation of sweat and consequently to an increase in the internal body temperature. This study aimed to evaluate if an Antarctic expedition with insulating clothing results in thermoregulatory adaptations to heat. Seven volunteers (30 ± 3.78 years; 71.66 ± 77 cm) performed a 45-minute run at 31ºC and 60% of relative humidity (RH) in a thermal chamber before and after a total of 72 days of voyage including 32-day camping (in a sub-Antarctic Livingston Island). During the 45-minute run, local sweat production ($TLS.gm^{-2}.min^{-1}$) and the number of active sweat glands ($ASG.cm^{2}$) on the forehead, forearm, chest, arm and thigh were recorded. Core temperature was also recorded. Student's t-test was used for comparisons between averages. P> 0.05. Compared to pre-Antarctica expedition values, post-Antarctic TLS increased (pre: 113.23 ± 23.38; post: 134.79 ± 12.00; P = 0.001) and ASG reduced on the forehead(pre: 135 ± 58; post: 61 ± 23; P = 0.018). The use of thermal insulating clothing during 32 days of an camp in Antarctic resulted in increased sweat efficiency on the forehead of young adults.

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Sleep pattern and mood state during a 50-day summer camp in Antarctica

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Antarctic expeditions include psychophysiological challenges, such as isolation, cold and extreme photoperiods (continuous exposure to natural light during summer); all of these challenges influence sleep. We assessed changes in night sleep patterns during displacement on a ship, 50-days in a camp (Nelson Island, S53.178533°/O70.899750°) and the post-field period on the ship, from Dec2019 to Feb2020. Sleep efficiency, time in bed, number of awakenings, wake after sleep onset (WASO), sleep time and sleep latency were determined daily in seven participants (5M, 2W) using actimetry (ActTrust,Condor). The expedition was divided in: Pre-field (6 days on board), Field-1 (1st week of field), Field-2 (days 8 to 20), Field-3 (days 21 to 35), Field-4 (days 35 to 50) and Post-field (4 days on board). Mood state was evaluated using the Brunel Mood Scale, and daytime sleepiness using the Epworth Scale, both applied between 7 and 9am. Relative to the Pre-field measurements, Antarctic summer camp reduced sleep efficiency by 4.8%, and increased time in bed, number of awakenings and WASO by 15.7%, 42.5% and 38.3%, respectively; all changes returned to Pre-field values during the Post-field. At Field-2, 3 and 4, excessive daytime sleepiness (score above 10) was observed. 'Confusion' was increased at Field 1, and ‘vigor’ was reduced at the end of camping (Field 4). There were no differences in sleep time, sleep latency, anger, depression, tension and fatigue. The present results suggest that a 50-day summer camp in Antarctica changes the sleep pattern, thereby increasing drowsiness and inducing occasional negative changes in mood.

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Effects of sprint interval training on physical performance and anthropometric, physiological and cognitive parameters in military personnel during an Antarctic naval expedition

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Military personnel participating in polar expeditions are subjected to environmental and behavioral changes resulting from naval confinement. Under the latter condition, sprint interval training (SIT) can be a non-pharmacological strategy for promoting health benefits in these individuals. This study aimed to evaluate the effects of SIT on physical performance, and anthropometric, physiological and cognitive parameters in military personnel during an Antarctic naval expedition. Sixteen men (35.2 ± 5.5 years) were randomly assigned to the following groups: SIT and control, non-training (NT). SIT consisted of 8 sessions: 5 to 7 sprints lasting 30s at 150% of the maximum aerobic speed attained during a pre-training incremental test; a 240-s recovery was allowed between sprints. The following parameters were measured before and after the intervention period in both groups: maximum aerobic speed (physical performance), adiposity (anthropometric parameter), heart rate variability, concentrations of blood thyroxine (T4) and salivary immunoglobulin A (IgA; physiological parameters), and working memory (cognitive parameter). SIT significantly increased physical performance [$P = 0.03$; effect size (ES) = 1.12] and reduced adiposity ($P = 0.04$; ES = 0.87) compared to NT. Moreover, SIT promoted moderate effectsin increasing cognitive performance (ES = 0.87), parasympathetic tone (ES = 0.61; 0.85; 0.69) and T4 concentration (ES = 0.66) and in decreasing IgA concentration (ES = 0.88). In summary, SIT can be an interestingly intervention to promote health benefits (e.g. improved aerobic fitness, body composition, cardiac autonomic control and cognitive performance) in confined military personnel during an Antarctic naval expedition.

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Risk management by leaders of wintering parties in Antarctica

Nobuo Naruiwa[1], Tetsuya Kawabe[2], Nanako Kato[3], Asako Sasaki[4], Tomoko Kuwabara[5], Giichiro Oono[6,7], Kentaro Watanabe[7], Satoshi Imura[7]

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Successive Japanese wintering parties were placed in an isolated environment in Antarctica for durations of about one year. They received few visitors because there were no other permanent research stations nearby. The environment was very stressful. However, all members completed their tasks with very few injuries and few big accidents.

Therefore, we focused on the quality of the risk management of the leaders of the wintering parties in Antarctica. We did semi-structured interviews of six former leaders of Japanese wintering parties. Three of them were leaders of parties in which members could hardly communicate with people in Japan because they sent messages only by telegraph. The other three were leaders of parties in which members could communicate with people in Japan at any time over the internet.

We found there were risks (1) associated with personal matters, (2) with wintering parties that were closed societies, (3) with the quality of the management of the leader, (4) with Antarctica, such as the climate and remoteness, and (5) with the connection to Japan during wintering. In particular, the risks associated with the connection to Japan were much stronger than before when members could not use internet. This lead to great changes in the quality of the risk management of leaders during wintering.

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A report on medical case with acute weakening of vision

-----An experience of telemedicine and medical evacuation of a patient with eye disease

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We experienced an acute eye disorder case which needed telemedicine support and medical evacuation.
Case Report: A participant of Syowa Station, male in his 30's, consulted a station doctor because of bloodshot eyes with pain, weakening vision after outdoor operations in November. Non-steroidal anti-inflammatory eye drops were used but shew no recovery. The doctor requested telecommunication by ophthalmologists. Television made it possible to examine visual field constriction, anterior chamber and conjunctiva clearly. Steroid drips were recommended but vision became worse. It was difficult to further therapy without more information such as fundus. A medical evacuation was decided, and the patient was sent to Japan by airplane in 6 days.
Discussions: Eye diseases counted 397 (6%) of 6837 medical cases in Syowa station between 1956 and 2016. It was the fifth-place following orthopedics, inner medicine, surgery, dental and skin diseases. Though eye diseases are usually non-critical, it is hard for patients to work in Antarctica and after coming back if they had aftereffects.

Telemedicine becomes indispensable in Antarctica. It is said to be useful especially in orthopedics and teeth trouble. Here, we showed it also effective in eye diseases, and it will work better with a fundus camera and tonometer.

This case is the fifth medical evacuation during 63 years of Japanese Antarctic expedition. Though there are great limitations such as impossibility in winter and melting sea ice used as a runway in midsummer, medical evacuation has been so developed as one of popular selective medical treatments.

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A report on medical case with acute weakening of vision

-----An experience of telemedicine and medical evacuation of a patient with eye disease

Giichiro Ohno[1], Kazuhiko Kasuya[2], Yoichi Miyaoka, Shinji Otani, Atsushi Ikeda, Satoshi Imura
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Evaluating Effectiveness of Monitoring of Oxygen Saturation at High Altitude in Antarctica

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Introduction: Antarctica is covered with a thick ice sheet that reaches up to an average of 2,450 above sea level (a.s.l.). Japanese Antarctic Research Expedition (JARE) has been doing research activities in extreme environmental conditions at high altitude where can cause health disorder including acute mountain sickness (AMS). To improving the safety of members during Antarctic expeditions, we evaluated the impact of extreme environmental conditions of the Antarctic inland on human health and effectiveness of monitoring of hypoxia for early detection of AMS.
Methods: In total, 9 members from JARE 59 were included in the study. Dome Fuji Station (Dome F), located 3810 m a.s.l., was the destination of the party. We investigated daily AMS scores (the higher value, the more severe AMS-related symptoms), physiological findings, and percutaneous arterial blood oxygen saturation (SpO2) during the inland activity. We also determined the factors related to AMS scores.
Results: The average AMS score at arrival at Dome F was significantly higher than at departure point (S16, 560 m a.s.i.). SpO2 level was negatively correlated with AMS score. In generalized estimating equations analysis, AMS score was positively associated with age ($p < 0.001$) and negatively associated with the level of SpO2 ($p = 0.035$).
Conclusion: Hypoxia is one of the factors related AMS and we can confirm easily hypoxic state from levels of SpO2. Monitoring SpO2 could be useful for health management of members in Antarctic inland activity.

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Dental Care in Antarctica as an Analogous Model for Planning Lunar Base Operations

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NASA is committed to return to the Moon in 2024 and to establish a lunar base for research and other activities. Due to its remote location and isolation, Antarctica serves as an excellent analog. Data from compiled research suggests that dental/oral health complications are the third most common healthcare occurrence among Antarctic bases. Data also suggests that over a 60-year period health complications while on Antarctic bases has been trending towards an increase on a per person basis. Some of the dental issues are of a serious nature and require medical transport from the continent for treatment. In general, dental training for medical providers is minimal and the available dental equipment may be inadequate. The study seeks to bring a better understanding of the dental equipment and training necessary to establish a lunar base. Consideration for equipment selection includes minimizing size and weight due to the cost of transporting such items to the lunar surface. This research shows that dental health will be a key issue to understanding and properly preparing for future lunar missions.

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Antarctica as an Analog for Commercial Spaceflight Medical Monitoring

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The advent of commercial space travel will present challenges for medical monitoring due to the diverse population wealthy enough to afford it. The Antarctic community is analogous to the commercial space population in that they do not fit the traditional image of the highly selected healthy astronaut population. Health conditions that have been disqualifying for spaceflight in the past will be commonplace among average space travelers and it is imperative to adequately monitor their medical conditions in order to assure the safety of the individual and the success of the mission. UTMB recently acquired a grant from the Federal Aviation Administration Center of Excellence for Commercial Space Transportation to develop new occupational medicine standards for the commercial spaceflight community. In the first phase of this grant, medical conditions that are expected to require monitoring are being identified along with the appropriate wearable devices to monitor those conditions. The second phase of the grant is focused on testing the devices in ground based analogs and on commercial astronauts in-fight. Antarctic medical data is used as an analog for evaluating common disease conditions in an austere environment and in determining the appropriate monitoring technology. Physicians in the UTMB Aerospace Medicine Residency Program have already performed preliminary testing of several wearable devices used for monitoring diabetes, circadian cycle disruption and sleep quality while on tour of duty to Antarctica associated with their residency training. Current progress on the development of spaceflight occupational medicine standards and monitoring technology will be presented.

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The Incidence of Injury in British Antarctic Personnel between 2007 and 2016

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Introduction
A recent incidence of injury in the British Antarctic population is not known, neither whether changes to health and safety policies have reduced it. The aims were to describe the profile of injuries experienced by British Antarctic Survey (BAS) personnel between 2007-2016.

Methods
Retrospective review of records, travel itineraries and incident reporting systems.

Results
Incidence of injury reduced from 661.7/1000 person-years (1986-1995) to 529.3/1000/year (2007-2016). 44.9% were picked up by the incident reporting system. New injuries were 21.1% of all consultations with 35.5% follow-up consultations. On average 65.1 consultations each month, minimum in September and maximum in January. Mean incidence on ships was 334.6/1000/year and 657.8/1000/year on bases. Peak incidence was at South Georgia (1182.6/1000/year) and lowest at Signy (130.2/1000/year). Peak major trauma was at Halley with 212/1000/year and peak work related injury at Halley also (547.5/1000/year). Commonest were sprains(47.9%), superficial(15.1%), wounds(11.1%) and fractures(8.5%). The most frequently affected occupational group were crafts and trades workers(32.4%), then professionals(22.1%).

Conclusion
Incidence of injury decreased compared to a similar study from 20 years prior. A report was created that profiles incidence and types of injury at each location with contributing factors of injuries in the BAS population in Antarctica. It can be used to train and inform doctors travelling South but also inform management and senior decision makers to enhance operational and strategic decision making. It produces a picture of injury that is also potentially of use to other national Antarctic programs and is useful as a comparison for health care interventions

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Monitoring human health indices using 3D optical whole body scanning

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Optical 3D (3DO) scanning has been proposed as an accessible self-assessment technology capable of estimating total and regional body composition and anthropometry measures, and ideally suited for remote environments (space, antarctic region). Our objectives were to predict DXA body composition, serum lipid and diabetes markers, and functional strength from 3DO body scans using statistical shape modeling and automated anthropometry.
Four-hundred and seven healthy adults underwent whole-body 3DO and DXA scans, blood tests, and strength assessments in the Shape Up! Adults cross-sectional observational study. Principal component analysis was performed on registered 3DO scans and 476 automated anthropometry measures acquired. Linear regressions were performed to estimate body composition, biomarkers, and strength.
We found that 11 PCs for each sex captured 95% of body shape variance. 3DO body composition accuracy to DXA was: fat mass R2 = 0.88 male, 0.93 female; visceral fat mass R2 = 0.67 male, 0.75 female. 3DO body fat precision was: RMSE = 0.81 kg male, 0.66 kg female. 3DO visceral fat was as precise (%CV = 7.4 for males, 6.8 for females) as DXA (%CV = 6.8 for males, 7.4 for females). Multiple 3DO PCs were significantly correlated with serum HDL cholesterol, triglycerides, glucose, insulin, and HOMA-IR. 3DO PCs improved prediction of isometric knee strength (R2 = 0.67 male, 0.59 female; anthropometrics-only R2 = 0.34 male, 0.24 female).
3DO predicted body composition with good accuracy and precision comparable to existing methods. 3DO PCs improve prediction of serum lipid and diabetes markers, and functional strength measurements.

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Unexpected high diversity of Legionella spp. in Antarctic environment and their colonization in Japanese Antarctic research station

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Legionella spp., potential pathogens of Legionellosis, are ubiquitous bacteria that inhabit in freshwater environments. Man-made water facilities are also common reservoirs which can be a source of infectious outbreaks. In polar regions, little is known about the occurrence and distribution of this bacteria, but from our previous investigations, Legionella DNA was continuously detected by PCR from Japanese Syowa station in Antarctica (69°S, 39°E). Our next aim was to elucidate whether these DNA were from humans or local environment and determine the presence of pathogenic species. We investigated the occurrence and diversity of Legionella spp. in both artificial and natural environments in Antarctica using Legionella-specific 16S rRNA gene-based amplicon sequencing. We will show the results of analyzing 33 samples of water and biofilm collected from glacier lakes (water, 22) and Syowa station water facilities (water, 3; biofilm, 8). 488 Legionella amplicon sequence variants (ASVs) with median of 93 (IQR, 81.0-122.0) were observed from lake samples and 207 Legionella ASVs with median of 14 (IQR, 5.5-29.5) from Syowa station samples. When comparing samples collected from these two sites, 50% of ASVs from Syowa station were shared with ASVs from lakes, whereas predominant ASVs in Syowa station were rarely observed in lake environment and that included ASVs nearly identical to potential pathogenic species. We found out that diverse Legionella spp. inhabit in Antarctic low-temperature environment. Some pathogens detected in the station were not related to those from the local environment, suggesting that they were originally transferred from outside Antarctica.

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The role of circadian phase on sleep, performance and mood in Antarctic over-winter expeditions

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The Antarctic environment presents extreme seasonal variation in the natural light-dark cycle. Differences in light exposure can cause variability in the alignment of the circadian pacemaker with the timing of sleep resulting in sleep disruption, and impaired mood and performance. This study assessed the prevalence of circadian misalignment and consequences for sleep, cognitive functioning and psychological health in over-wintering Antarctic expeditioners. Fifty-one expeditioners (45.6±11.9 years) completed daily sleep diaries and monthly computer-based performance tests and psychological health questionnaires. Circadian phase was assessed via monthly 48-hour urine collections to assess the melatonin metabolite 6-sulphatoxymelatonin (aMT6s) rhythm. While the average sleep duration was 7.2±0.8 hours, 41.2% of sleeps were <7 hours and 19.1% were <6 hours. Circadian phase was highly variable and 34/50 expeditioners had sleep episodes occur at abnormal circadian phase. This accounted for 18.8% (295/1565) of their sleeps. Expeditioners obtained less sleep on average during misaligned sleep episodes (6.36±1.19 h), compared to aligned (7.17±0.95 h, $p<0.0001$). Performance and mood varied in a predictable manner with circadian phase and time since waking. This research highlights the prevalence of misalignment between the timing of sleep and the circadian pacemaker in Antarctic over-wintering expeditioners. Similar prevalence has been observed in long-duration space flight, reinforcing the fidelity of Antarctica as a space analog. The effects of circadian misalignment have immediate safety implications, and potentially longer-term health risks for other circadian-controlled systems. This highlights a need for appropriate interventions, such as properly planned lighting solutions, to ensure circadian alignment during long-duration Antarctic and space missions.

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Everest 2020: How will COVID-19 affect the Everest 2020 climbing season? Can infection control lessons from the world's third pole be extrapolated to the south pole?

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Beyond the daunting challenge of climbing Everest, each climbing season, running April to May, has its own unique challenges. There were no summits in 2014 and 2015 following the devastating consequences of a serac collapse (2014) and the Gorka earthquake (2015.) 2017 saw an influenza outbreak seriously curtail the summit chances of many mountaineers. The "fake rescue" scandal tarnished the 2018 season whilst the 2019 season suffered from a limited summit window resulting in crowding with subsequent deaths and international media outrage. Through it all, the volunteer physicians at the Himalayan Rescue Association (HRA) Everest ER Aid Post work tirelessly to take care of the climbers as well as the Sherpas, porters, kitchen staff and camp staff.

In 2020, the Everest climbing season faces a new threat, COVID-19. In early March, Nepal effectively shut the border to climbers from 5 countries; China, Korea, Japan, Italy and Iran, whilst athlete sponsors have withdrawn funds and climbers have cancelled plans. Teams that normally climb from Tibet's northern side of Everest have either withdrawn or switched to the south. Other teams are requiring athletes to arrive into Kathmandu two weeks earlier than normal to self-quarantine. At the time of writing, Nepal has only recorded one case of COVID-19, although the lack of cases is probably due to the lack of testing rather than a lack of prevalence.

Will these measures be enough to protect the health of Everest climbers? Will there be further challenges? How will the 2020 Everest season pan out?

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House dust mite monthly survey in an Antarctic wintering base

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In the Antarctic, some patients present symptoms similar to those of allergic rhinitis. Although the house dust mite allergen was detected in an Antarctic base, the concentration was too low to elicit an allergic reaction. We surveyed house dust mites (Dermatophagoides spp.) and their allergens, monthly, to validate whether their concentration reaches symptomatic levels in any period. We surveyed house dust mite population and allergen levels once a month at three fixed observation points in Syowa Station, an Antarctic wintering base. The allergen level was measured with a portable device using monoclonal immunochromatography. The mite population was measured by microscopically counting the number of mite bodies. Simultaneously, we measured temperature and relative humidity at these observation points. Neither the house dust mite body nor allergen were detected in any month of the observation year. However, we detected Rhizoglyphus sp. (bulb mite). We consider that the mite could have been present in the cargo brought into the Antarctic base. For house dust mites, surviving, reproducing, and being the cause of allergic rhinitis is difficult in the Antarctic bases due to indoor hygrothermal environment. However, pathogenic alien arthropods such as Rhizoglyphus spp. could be brought even into the Antarctic.

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Sleep pattern during the stay at the Brazilian Antarctic Station

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From a physiological perspective Antarctica has a very challenging environment whereas cold, confinement, wind and sensory monotony are considered stressful stimuli for the human body. In addition to these factors, Antarctica has extreme photoperiods, with long periods of light in the summer and darkness in the winter. The aim of this study is to investigate the pattern and quality of sleep of fourteen military volunteers during their stay at Brazilian research station in Antarctica. The volunteers from the Brazilian Antarctic Program are being evaluated over a six-month stay at the Comandante Ferraz Antarctic Station (Admiralty Bay, King George Island, Antarctic Peninsula), between summer and early winter (January, March and May), during Brazilian Antarctic Operation 2019/2020. Time in bed, sleep time and sleep latency, number of awakenings, sleep efficiency and wake after sleep onset (WASO) will be evaluated, based on data obtained every two months using actimetry (ActTrust, Condor). We will test the hypothesis that there is a change in sleep pattern and in the quality of sleep between the summer and early winter periods during the stay at an Antarctic research station.

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Brazilian individuals traveling to Antarctica on board a ship present changes in the thyroid hormones concentration and mood state

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Displacement to Antarctica usually occurs on board ships, which represent an isolated and confined environment with artificial luminosity, particularly inthe cabins and main areas of coexistence. There is evidence that days of total darkness in Antarctica (i.e., reduced exposure to natural luminosity) can induce the "polar syndrome" that is characterized by an increase in thyroid-stimulating hormone (TSH) simultaneously to a reduction in thyroxine (T4).This study aimed to assess whether travelingon board a polar ship changes thyroid hormones (TSH and T4) concentration, which can lead to important metabolic and mood changes. The volunteers (n = 17, all tropical inhabitants) spent three weeks on board the Brazilian Ship Alte. Maximiano (H41) during summer.Data collection was carried out 4 and 19days after boarding in Punta Arenas (Chile). Blood samples were collected and analyzedby fluoroimmunoassayto determine TSH and T4 concentrations,and mood statewas evaluated using the Brunel Mood Scale (BRUMS).Student t-test was applied; $\alpha = 5\%$. Data are presented as means ± SD. Compared to the initial measures, T4 reduced by 6.6% at the final measure ($P=0.023$), whereas TSH remained unchanged ($P=0.63$). Also, there were increases in Anger (0.8±1.1 to 2.5±2.7; $P=0.027$) and Depression (0.5±0.6 to 2.1±2.6; $P=0.038$) and a reduction in Vigor (9.2±3.2 to 7.6±2.4; $P=0.044$). In the context of an Antarctic expedition, short-term ship travels reduce the concentration of T4 and provokes negative changes mood in tropical inhabitants, possibly due to reduced exposure to natural luminosity.

SCAR 2020

Antarctic Science - Global Connections

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SESSION 43

EMERGING TECHNOLOGIES AND THEIR APPLICATIONS FROM THE DEPTH OF THE OCEAN, TO THE DEEP ANTARCTIC FIELD AND SPACE

Takashi Yamanouchi, Francis Bennet
Lize-Marie van der Watt,Wilson Wai Yin Cheung, Kimberlee Baldry

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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New Ship - New Possibilities

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The first explorers of Antarctica ventured to the continent via ship and on the way collected large amounts of scientific data. Still to this day, large proportions of Antarctic research is done on vessels in the waters in and around the continent. With the RRS Sir David Attenborough the British Antarctic Survey is continuing the tradition of ocean exploring in the Southern Ocean. The new vessel brings with it new technology, new opportunities, and inspiration for both its first users as well as future generations. Capabilities of the ship includes, but are not limited to, seismic operations, piston coring, full ocean depth camera systems, Remotely Operated Vehicle (ROV) operations, Automated Underwater Vehicle (AUV) operations, acoustics, trawling, fishing, helicopter operations, and subsea fibre optic cables. The ship itself contributes new technology, but its main purpose is to enable the research that is undertaken on it to be ground-breaking and innovative. How does one facilitate this? A good working relationship between scientists, researches, engineers, and ship's personnel. Future-proofing and modular thinking – making sure there is room to solve problems we might yet not have thought about. With the RRS Sir David Attenborough, the British Antarctic Survey are welcoming in a new age of research. This talk will explore the technological capabilities of the new ship, but crucially how to facilitate and future-proof this research through modular thinking.

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Advanced capabilities and innovation for Australia's dedicated blue-water research facility

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The Marine National Facility (MNF) provides a blue-water research capability to the Australian research community and their international collaborators. The MNF is funded by the Australian Government and owned and operated by CSIRO on behalf of the nation. The facility comprises the ocean class Research Vessel Investigator; a package of scientific equipment and instrumentation; a collection of marine data; and the expertise to manage an ocean-going research platform and support vessel users. The research delivered from MNF voyages provides important information to directly support government, industry and other stakeholders in making evidence-based decisions to enhance the long-term viability and prosperity of the Australian marine environment, industries and society, bridging the Australian and Antarctic regions. Doing research in the world's third largest marine estate is challenging. Researchers must have access to the most advanced and fit-for-purpose infrastructure to remain at the forefront of global marine and atmospheric research. The MNF is responsible for maintaining its science capabilities and upgrading them as required, as well as for expanding in response to new and emerging technologies and needs. It also offers significant opportunities for advancing technology development for novel marine science systems and technological solutions that can support the growing blue economy. The MNF has developed a 25-year Capability Investment Framework for the identification, prioritisation, procurement and review of capital investment through the remaining life of RV Investigator and beyond. The Framework identifies gaps in marine research infrastructure capability in Australia and proposes a roadmap for securing investment towards acquiring high-value strategic capabilities.

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How accurate are chlorophyll a fluorescence measurements from Biogeochemical-Argo profiling floats in the Southern Ocean?

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The Biogeochemical Argo (BGC-Argo) program has increased sampling of chlorophyll a in the Southern Ocean, filling the limited capabilities of ship-based sampling. The program has led to large-scale deployments of profiling floats equipped with in-situ fluorometers, measuring chlorophyll a fluorescence from live phytoplankton cells. As measurements are not performed ex-situ on extracted pigments, yields of chlorophyll a fluorescence (i.e. the ratio of absorbed light to emitted light) leads to the variability of the fluorescence-to-chlorophyll a concentration ratio. Regional corrections for this variability are sometimes performed by linearly regressing fluorescence against chlorophyll a concentration.

In the Southern Ocean, yields of chlorophyll a fluorescence are much higher than the rest of the world, and can change dramatically across fronts. Additionally, the effects of non-photochemical quenching of daytime fluorescence can reduce accuracy if not properly corrected. In the wake of the incorporation of BGC-Argo measurements into the validation of biogeochemical models and satellite-derived chlorophyll a concentration estimates, it is timely to review the accuracy of these measurements.

In this context, I will present here the variability of chlorophyll a fluorescence to chlorophyll a concentration ratios from a large aggregation of ship-based data. From this, I will explore the implications of this variability on the accuracy of BGC-Argo measurements and possible methods for correcting chlorophyll a measured from the BGC-Argo fleet.

This work is a collaboration between Australia (UTAS-IMAS) and France (CNRS-IMEV-LOV), supported by the SCAR Fellowship program and the Antarctic Gateway Partnership.

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Southern Ocean data: A community effort to build a data ecosystem

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The Southern Ocean Observing System (SOOS, https://www.soos.aq/) bridges oceanographic and polar science programs, and is one of the most intensely international scientific communities, thanks to the logistical challenges of conducting science in these remote waters. The users of Southern Ocean data are therefore highly heterogeneous in terms of their needs and expertise.

Serving such a diverse research community requires data management systems that are flexible and focus on integration of existing data products, rather than trying to duplicate existing work. Fortunately, new data sharing technologies are emerging that allow us bridge many of those gaps. The Southern Ocean Observing System is working with both the science and data communities to design an ecosystem of data management tools, catalogues, and systems for polar oceanographic research. It also requires a cultural change among science programs - one that generates FAIR data (Findable, Accessible, Interoperable, and Reusable) at the heart of scientific activities.

Key components of the SOOS data vision include data and metadata discovery tools, fieldwork coordination tools, and linking data collections with analysis tools. Just as important are the people and communities who develop, link, and use these components. We will share our experiences in working with EMODnet Physics to develop SOOSmap - a portal to explore, graph, and download curated spatial datasets of key observations. We will also focus on the challenges and need for a federated metadata search tool to improve access to a much broader range of polar oceanographic data than can be served directly through SOOSmap.

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Hybrid Autonomous Underwater Vehicle for biological sampling of Antarctic sea bed.

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Robotics technologies have a key role in the exploration of Antarctica. Usually Remotely Operated Vehicles (ROV) are used to explore and get biological samples from the seabed. Deploying a ROV to reach depths greater than 1000 m at the South Shetland Islands requires a large logistic support to handle the umbilical cable and energy requirements, typically the ROV is deployed from an oceanographic vessel. Our approach is based on small Autonomous Underwater Vehicle that can perform some tasks of an ROV without human intervention like get close images of a scientific point of interest and collect biological samples from the seabed. A man-portable Hybrid AUV was developed as a test stand for a computer vision and Artificial Intelligence systems to perform some complex tasks of a ROV with human operators like identify sites of scientific interest and make parking strategies to collect underwater samples. The hardware-software architecture is based on low cost FPGA and ARM processor development boards to implement an Inertial Guidance System, Computer Vision, Stochastic Optimization and Convolutional Neural Networks. The software is coded by VHDL language running on an FPGA and C/C++ scripts running on an Embedded System. The AUV was deployed during the Ecuadorian Expedition 2018-2019 to Pedro Vicente Maldonado Scientific Station, making a photogrammetric survey and biological sampling in the submareal zone. A future work is to install this software on a man-portable AUV rated for 6000 m that is under development to get deep sea samples near to the South Shetland Islands.

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A Modular Autonomous Biosampler (MAB): Multi-platform system for distinct biological size-class sampling & preservation of sea ice and water column communities.

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We know little about the succession and maintenance of the biological community intimately associated with sea ice. This is due to our inability to efficiently and reproducibly sample the underside of the ice and water column throughout the year. What is needed is an instrument that can be adapted to multiple mobile platforms (e.g. AUVs, Gliders, etc.) servicing a range of applications across the Antarctic biological oceanographic community. The unit should be able to sense its environment, operate autonomously, and collect large numbers of discrete samples from multiple size classes that are preserved in situ.
We present the results of a 3-year development program aimed at building and fielding a low-cost, high-sample-capacity modular, autonomous biological sampling device. The presentation will focus on the development of a standalone unit that has been designed specifically for Antarctic deployment. We will present the specific design criteria that has guided the MAB development including: 1) The ability to collect 150 samples in each of any 3 size classes including bacteria (0.2µm); 2) The preservation of each individual sample in a fixative conducive to standard biological systematics and genetic analyses; 3) The ability to sterilize the water flow path between each sample; 4) The ability to detect and react to filter clogging; 5) The development of an environmental sensor module that will enable integrated “smart” sampling on the moorable unit; 6) the design of a retractable spooled intact umbilical that enables the system to sense, sample and profile the water column underlying the sea ice.

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Small-sized photovoltaic panels based on natural dyes at the antarctic Artigas Base.

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Dye-sensitized solar cells (DSSC) constitute an alternative to conventional photovoltaic-silicon cells. Based on the use of coloured dyes as photosensitizers, they can harvest the light in the visible range of the spectrum to generate an electric current.
The use of natural dyes shows efficiencies values up to 2 %.
In this work, we assembled two small panels based on anthocyanins extracted from Erythrina Crista-Galli flowers, the Uruguayan national flower. In one panel DSS cells were connected in series (7 cells, 5 cm2 total area), and in the other were in parallel (13 cells, 9 cm2 total area). In the latter, a 5 k⍰ resistance was included in the external circuit to allow the calculation of the generated power.
Individual performance of the cells was checked previous to panels' assembly. Panels were installed indoors in the Uruguayan Antarctic Base and remotely monitored since March 2019.
Potential values were evaluated across the hours of the day and during the different seasons. The results were also compared with irradiance values.
These alternative small panels could be used to supply small scientific measuring devices at Antarctica. As far as we know, this is the first time that DSSCs were installed on this Continent.

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A portable optical communications ground station for high rate data link to Antarctica

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Transmission of data from the Antarctic continent is reliant on radio transmission to satellites which limits the amount of data that can be sent across the world. The remoteness and harsh conditions of Antarctica mean a physical fibre link is not possible. Free space optical communications is a method which could provide a high rate data link in remote locations such as Antarctica.

The Research School of Astronomy and Astrophysics (RSAA) at the Australian National University (ANU) is developing a portable ground station which can be used for optical communications in Antarctica. Data is transmitted from the ground station to a satellite which will be developed to support the mission. The satellite will downlink data to a network of stations positioned across Australia and New Zealand. The ground station network provides diversity in receiver sites that will reduce downtime of the system due to poor weather.

The development of optical communications to Antarctica could enable data rates over 10 times larger than is currently available. This would allow real time transmission of scientific data to the world which could transform how science is done in Antarctica.

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Expanding the Reach of Science Under Ice: Opportunities for Custom Sensor Integration on Icefin

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Icefin is an ROV/AUV designed to relax the significant constraints that ice cover puts on polar science. Meters to kilometers thick ice has historically limited scientific data, particularly in remote areas of ice sheets. Icefin meets this challenge by fitting through ice boreholes. While most borehole equipment can only move vertically, Icefin can precisely explore along transects from the ice interface to the seafloor limited only by its tether and stored energy, with typical round-trip missions of 2-4km, expanding the reach of science equipment. Thus far, Icefin has collected a range of scientific data over three years of deployments through sea ice as well as through 600m of ice at the Kamb Ice Stream and Thwaites glacier. Icefin includes a flexible science bay that has been designed to enable us to develop instruments and work with instrument providers to achieve more science. In addition to integrating 10 different kinds of off the shelf science sensors for use on the vehicle, we are currently developing standards for instrument integration to streamline incorporating existing and new scientific equipment. Currently we are developing a water sampler, digital holographic microscope, and sampling arm in our lab, as well as working with a team designing a novel instrument to investigate supercooling. Our continued development of Icefin gives us a unique insight into best practices for power and communications interfaces. Here, we hope to share our insights and discuss new ideas with the scientific community presented with similar challenges, and to encourage future collaboration with Icefin.

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Polar Thematic Exploitation Platform: A shared virtual environment for finding and using Earth Observation data over the polar regions.

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[1]British Antarctic Survey, Cambridge, United Kingdom, [2]Polar View, Harwell, United Kingdom

We propose a talk about the Polar Thematic Exploitation Platform (www.polartep.io).

Earth Observation (EO) has a unique and important role in the polar regions as the only consistent source of regular, year-round, calibrated regional scale data for the polar regions. However the volume and variety of EO data available for the polar regions is growing rapidly, providing opportunities for more complex applications by polar scientists. This trend is forecast to continue given plans for new polar focused satellite instruments, including new Copernicus Sentinel expansion missions. This situation is not limited to the polar regions and other domains face the same challenges of increasing data volume and how to fully process, analyse and exploit them.

As a result, novel cloud-platforms have emerged to provide online research environments collocating data and processing capabilities, plus development, analysis and visualisation tools. These platforms offer a solution to the challenge of exploiting greater volumes of EO data and dramatically simplifying access for a wider range of polar scientists, without requiring local computing infrastructure.

The Exploitation Platforms established by the European Space Agency, include the Polar Thematic Exploitation Platform. This presentation will describe Polar TEP capabilities and planned evolution, covering available polar EO datasets, toolboxes and processing capabilities, plus functionality to allow deployment of user defined workflows. We will also outline new PTEP features which allow easier batch and automated scheduled processing of large data volumes and integration of machine learning workflows; all using the recently established European DIAS (Data and Information Access Services) data platforms.

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Harnessing the Data Revolution to Characterise Seafloor Communities Adjacent to the Larsen C Ice Shelf, western Weddell Sea, Antarctica: A Citizen Science Inclusive Approach to Accelerate Analysis to Inform Ecosystem-Based Marine Management

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Manual interpretation of remotely-captured seafloor imagery is the principal method of generating information to characterise benthic communities and ecosystems, including establishing baselines. The method is exceptionally time-intensive; with researchers also having to balance such appraisals with other competing commitments. As the capacity to capture data is increasing, both technology- and storage-wise, we are facing a “data deluge”, with potentially important findings hidden in the heap.

Without evaluation of imagery, drivers of compositions and distributions cannot be discerned, nor potential changes in ecological systems with environmental changes predicted.

Given the current rate of environmental change, both globally and Antarctic-specific, the existing time-lags, between acquisition and results-provisioning, used to inform conservation and ecosystem-based management decisions, are concerning. It is vital that the evidence-base is provided in a more timely manner.

Looking towards solutions, the harnessing of people-power, in particular citizen scientists, may provide an effective means to resolve issues. Co-benefits would include increasing public awareness, galvanising interests in Antarctica on the whole, and raising the profile of its relatively unknown seafloor ecosystems and inhabitants.

It can be envisaged that a conceptual approach incorporating a crowd-sourcing platform coupled with machine learning (automation) may facilitate in combatting the above-mentioned bottleneck, and expedite future seafloor evaluations; in the best-case scenario process-wise bypassing manual interpretation.

This approach, interweaving disciplines, emerging technologies and public-participation, is first applied to seafloor imagery collected during the SA Agulhas II Weddell Sea Expedition 2019 to the Larsen C ice shelf, and represents a progressive step in seafloor imagery analysis.

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Direct Evidence of Nitrate Aerosol Formation in Summer Antarctic Stratosphere Obtained by a Balloon-Assisted Unmanned Aerial Vehicle

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The system for the stratospheric aerosol observation and sample-return in Antarctica using the combination of a rubber balloon and an Unmanned Aerial Vehicle (UAV) has been developed. The balloon-UAV system reaches 20km to 30km in altitude, but it becomes difficult for the UAV to directly glide back autonomously after separating from the balloon at higher altitudes because the aerodynamic characteristics necessary for the control system design at higher altitude is difficult to obtain. In order to avoid the problem, the two-stage separation method is proposed in which the UAV first descends down to a flyable altitude of the UAV by a parachute after separating from the balloon, then it separates the parachute for autonomous gliding back to the released point. An optical particle counter and an aerosol sampler installed in the UAV were launched on January 24, 2015 from S17 (69.03 S, 40.09 E, 607 m a.s.l.) near Syowa Station in Antarctica. A stratospheric aerosol layer composed of three sub-layers is quite distinctive compared with a typical stratospheric aerosol layer, which suggests the effect of the eruption of Mt. Kelut on February 14, 2014. An electron micrograph of the stratospheric aerosol sampled at 22km in altitude suggests the existence of nitrate particles with sub-micrometer diameters in spite of the high temperature around -45 degrees Celsius at the sampled altitude. They also show that the balloon assited UAV system is a useful method for polar upper atmospheric research.

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Thermal response of antarctic plants using an automatic sensors actuators network

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The study presented in this work is a continuation of a research conducted in Maritime Antarctic, which investigates the effects of the future warming scenario on the only two vascular plants inhabiting Antarctica: Deschampsia antarctica and Colobanthus quitensis. Until the moment, the methodology used to simulate future warming involves the use of a passive warming system: Open Top Chambers (OTCs). This system enables average temperature increases of OTCs microenvironment in about 4°C compared with open site (OS). However, the OTCs has its effect only during the day, while during the night, the temperatures inside them are almost equal or even lower than OS (Minimum Night Temperature registered 2015-2016 summer season: -3,6°C OS vs -4,8°C OTC). This OTC artifact is contrary to the predictable asymmetric warming, which is the tendency to an increase in the daily minimum temperature than in the daily maximum temperature; and this could be the reason to there is no effects on the freezing tolerance of both species along the antarctic growing season. Laboratory results indicated that D. antarctica, only cold deacclimated, when night temperature increase; though, these short terms periods has not effect in C. qiutensis. However, long term studies must be performed to fully comprehend the warming effect in these plants physiologies. To fill this gap an active nocturnal warming system was elaborated and implemented. This paper reveals some of the design and implementation issues, together with the result of thermal response measurements of both species in the vicinity of the Polish Antarctic Station “Arctowski”.

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Airborne comprehensive observation on aerosol transportation into the Antarctic interior using UAV

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Atmospheric circulation transports aerosols (fine particles in the air) into the Antarctic interior, and the aerosols accumulate on the ice sheet, which can modify climate and are the sources of climatic markers found in ice cores. The climatic markers reflect the principal atmospheric circulation pattern in those ages. For understanding the past atmospheric circulation, it is important to know how aerosols are transported into the Antarctic interior with atmospheric circulation in the present age. Thus, in order to identify the transportation mechanism of aerosols in the lower troposphere from the ocean onto the ice sheet, a field operation was carried out at inland observation site S17 (69°02′ S, 40°04′ E) on the ice sheet for 45 days in the 2016/17 summer season. UAV (Unmanned Aerial Vehicle), called Kite-plane, was employed for observing spatial and temporal variations in distribution of aerosols between S17 and a coastal area about 20 km away. Full-course return flights were carried out 11 times among 24 times of the observation flights during this field operation. The success of the comprehensive scientific observation employing UAV is a first for JARE.

The data show different transportation mechanisms of aerosols from the ocean onto the ice sheet. In one case, the number of particles are larger in the lower boundary layer only on the coastal side. In another case, large numbers of particles only in the upper layer were found, which can transport aerosols to the Antarctic interior.

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Data management in MOSAiC – Challenges of the Multidisciplinary drifting Observatory for the Study of Arctic Climate

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During the MOSAiC expedition, the German research icebreaker Polarstern spends a full year drifting through the Arctic Ocean. Scientists from 20 countries participate in the largest polar expedition in history exploring the Arctic climate system. The experiment covers a large suite of in-situ and remote sensing observations of physical, ecological and biogeochemical parameters to describe the processes coupling the atmosphere, sea ice, and ocean.

In addition to forefront instrumentation and observational techniques, proper data management is essential for large and complex projects and field programs. Key elements are agreements on consistent sampling strategies, the possibility to monitor the data flow, to facilitate near real-time processing, and analysis and sharing of data during and long after the expedition. Furthermore, data publication and documentation are crucial for such a collaborative effort and will build the legacy of the project and finally take climate science to the next level.

We adapted our modular research data management framework O2A “Data flow from Observations to Archives” to meet the expedition requirements and ensure central data archival for generations to come. Researchers register all necessary sensor metadata beforehand. Essential metadata of scientific actions in the field are ingested immediately with the FloeNavi, a novel system enabling navigation on a drifting ice floe. O2A provides tools to automatize data ingestion, monitor the data flow and process, analyze and publish data. Integration of ship- and land-based components and a shared storage ensure seamless continuation of collaboration during and after the expedition laying the fundamentals for numerous data publications.

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Implementation of an Eolic turbine in Antarctica

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The objective of this project is the design and manufacture of a Wind Turbine prototype in Colombia for its implementation in Antarctica. Taking advantage of extreme wind currents, which are abundant and constant throughout the year, being a friendly energy with the environment and the best option when implementing a Colombian Antarctic base, contributing to the policies of the Antarctic treaty, being a model of development for the country as pioneers in the field of implementation of renewable energies and in turn, managing to mitigate the logistical impact of fossil fuels, a task that requires excessive labor and many hours of flight which are unnecessary before the possibility of using an Aeolian Turbine, saving high costs of these operations. During the month of December of the year 2015 there was a participation in the Antarctic Base of Marambio with the objective of identifying in what and how much electrical energy is consumed, as well as a preliminary measurement of winds with a portable weather station, the previous thing to design the Turbine prototype which was implemented for the current year 2018 in the Antarctic Base of Marambio, obtaining positive results with Polar winds of 40 knots, temperatures of -50ºC and generating between 3 and 5 KW, being the implementation of it a great success since a challenge and experience for the deployment of the generator from Colombia and its installation. Both missions are possible thanks to the collaboration of host country Argentina.

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The Ice-o-pod: A custom built Remote Operated Vehicle for conducting quantitative benthic photographic surveys through sea ice.

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Monitoring change in remote marine communities can be logistically challenging, particularly where sea ice exists for most of the year. In early summer, coastal Antarctic sea ice is thick, providing a reliable work platform from which to access benthic habitats. Underwater visibility is at its best at this time of year, ideal for conducting video and photographic surveys of benthic communities using a Remote Operated Vehicle (ROV). In the Vestfold Hills near Australia's Davis Station we drilled a 40 cm diameter hole in the sea ice through which a 35 cm wide custom designed and built ROV, nicknamed the Ice-o-pod, accessed sea floor habitats. An altimeter allowed constant adjustment to achieve a consistent flight 1 m above the sea floor. Two downward facing GoPro cameras collected video and photo imagery including scale points projected onto the sea floor from an independent laser unit. We conducted down-slope and across-slope photographic transects at ten sites with the resulting quantitative analysis of photoquadrats documenting complex, diverse marine invertebrate communities associated with a variety of sea floor habitat types. The combination of through ice access using a small, portable, hand-held auger drill and an ROV deployable through the resulting narrow hole proved logistically successful, requiring relatively little equipment which was easily transported and operated by a minimum of two people. The malleable nature of current ROV technologies provides potential to refurbish and add additional technologies to meet and expand future research needs and possibilities.

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The Polar Climate and Weather Station (PCWS): A New Electronics Core for Observing the Meteorology and Climate over the Antarctica Surface

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2020 marks the 40th anniversary of the establishment of the Antarctic Automatic Weather Station (AWS) network. The modern day network is populated by contributions from many national Antarctic programs and groups from around the world. Over the years, the equipment that makes up an Antarctic AWS has evolved. Original AWS systems where often institutional built, home-made systems and today's modern network is primarily commercial-off-the-shelf. This project focuses on the development of a new electronics core for the future, using readily available components, and tested for Antarctic application. This effort does not develop new sensor systems, but does utilize proven sensor sets and enable the expansion of sensors to be standard on the PCWS. To ensure the observations are climate worthy, multiple temperature sensors will be installed at standard height following what is found in other climate observing networks such as the US Climate Reference Network, and opposed to the single sensor which is currently ubiquitous across the Antarctic. This effort is a student-centric effort at all levels of this project, from proposal, to development, onto execution, and ending with deployment of the first running system. With project successes, more work remains. This presentation outlines the PCWS project, its status and future.

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Antarctic Deep Field Deployments and Design of the Icefin ROV

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Icefin is a remotely operated under water vehicle (ROV) designed with a focus on portability and modularity for exploring ice environments. We are able to explore extremely remote areas of the Polar Regions here on Earth with Icefin and its various payloads, developing both engineering technologies and scientific hypotheses to one day explore the ocean worlds of our solar system. Icefin was developed specifically for borehole deployments and is outfitted with oceanographic sensors, biogeochemical sensors, multibeam sonars, and an array of imaging systems. The Icefin prototype was deployed through sea ice off McMurdo Station in 2014. Since the vehicle's redevelopment in 2017, Icefin has spent over 160 hours exploring ice covered ocean. Icefin enables several novel operations scenarios that permit the vehicle to conduct missions ranging from glider-like ocean surveys to sonar collection, while allowing the vehicle to hover and explore interfaces directly. In 2019, we built a second vehicle to facilitate simultaneous field deployments under the Ross Ice Shelf and Thwaites Glacier. Between the two campaigns, Icefin completed 50 hours of diving and surveyed 17km over 8 missions through 600m of ice. Icefin explored both the grounding zone of Thwaites Glacier, swimming into a water column only 0.5m high, and profiled a 50m tall basal crevasse under the Ross Ice Shelf. Icefin details will be presented, along with lessons learned and results of deep borehole deployment. We hope that by sharing our experiences and design decisions with the community, the possibilities in this area can be advanced through collaboration.

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Shallow-water scavengers of polar night and day – an example of a time-lapse photography study from the Arctic

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Scavengers being a link in the nutrient and energy circulation are an important part of benthic communities worldwide. Highly seasonal environments with prolonged periods of total darkness during winter and only short but intense production events during spring/summer, such as polar seas, are regions where necrophagy is a frequently used strategy. In contrast to Antarctica, however to date there is very little works describing shallow-water scavenging assemblages from the Arctic, especially those from the polar night. We traced the decomposition of two different bait types (cod Gadus morhua, and chicken meat) during polar night and polar day at 14 m depth in Kongsfjorden, Spitsbergen Island (78° N) with specially designed time-lapse photography systems equipped with small baited traps. A total of 31 taxa were identified from photographs. In most of the cases buccinids (B. undatum, B. glaciale.) and lyssianasid amphipod Onisimus sp. were the first species at bait. The latter species made up 88% of the total number of animals counted, however it occurred infrequently (55%) mostly during winter. The most frequent species were buccinids, hermit crab Pagurus pubescens and another representative of Amphipoda, Anonyx sp. PERMANOVA analyses indicated a clear differences between the investigated seasons, bait types, as well as an interaction of both factors, independently whether only presence-absence or whole community data were used. The method proved to be successful to investigate scavengers feeding preferences, and their interspecific interactions at bait.

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Progress in Optically-powered Ice Penetrators

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Stone Aerospace has continued work on an optically-powered ice penetrator. The ARCHIMEDES cryobot uses patented Direct Laser Probe (DLP) technology wherein laser light from a surface-based laser travels to a probe via a fiber optic tether that is spooled onboard the vehicle and is paid out as the probe descends. The laser emission travels through a series of lenses in the probe nose before exiting the probe and being absorbed into the ice, where it induces melting and the probe descends under its own weight.

Originally developed under NASA funding for outer planet robotics, DLP can be adapted for use in terrestrial glaciated environments as a clean-access tool to investigate thick ice sheets, ice shelves, and subglacial water bodies. The approach can potentially be scaled to work through more than 4000 meters of ice. Initial calculations indicate that at high power, a 5 cm diameter DLP probe could be used to reach 4000 m penetration in 16 hours in Antarctic ice temperature profiles with 60 kW of power reaching the probe. The compact and simple design means that the probe can be sterilized prior to deployment to satisfy clean access protocols without complex on-site sterilization procedures.

Here we present recent laboratory test results of DLP technology operating in ultra-cold temperatures and show designs for an ultra-low-footprint, 4000 meter capable Distributed Temperature Sensing instrument field installation system.

1392

Fully Autonomous Behavior-Based Exploration of Restricted Access Sub-surface Environments

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In August 2019 the autonomous underwater vehicle SUNFISH completed the first robotic exploration of previously unmapped caverns. Three sites of increasing topological complexity were explored: Lake Guinas, Harasib Shaft, and Dragon's Breath Cave, all in northern Namibia. In each, a subterranean water body of unknown extent existed at varying depths below the surface. These sites provide an analog for advanced sub-glacial and sub-ice shell missions both in terms of providing a completely unknown environment as well as restricted access whereby the vehicle must absolutely return to at the conclusion of a mission or be lost. This represents the identical problem presented by drilled shaft access beneath the Ross Ice Shelf, e.g., or access to any of the interior deep sub-glacial lakes. In each of these GPS-denied situations the rover is entirely dependent on its own internal navigation system.

SUNFISH uses a multi-stage navigation system to create 3D maps as it proceeds into unknown spaces while registering its position and orientation within that map. The vehicle is a six degree of freedom hover-capable platform. It rotates, sweeping 120-degree fan-like multi-beam sonar to build complete spherical knowledge of the world about it within a 120 m radius. Behavioral routines then react in real time to real world data while the vehicle is moving forward. Alternative science behaviors can be superimposed onto the basic exploration behavior.

Here we present results from the cave exploration work and describe how this technology could be used for advanced subglacial lake and sub-ice shelf autonomous science.

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Glider-derived Determinations of Vertical Flux and Iron Limitation in the Ross Sea

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Gliders have become increasingly used in oceanographic studies in the Southern Ocean, largely due to their ability to sample small spatial scales and over long time periods, providing information that ship-board investigations cannot obtain. However, gliders are also limited in terms of what they can routinely measure, as sensors for biogeochemical studies are limited. We describe procedures that use glider data to investigate the temporal variations in both vertical flux and iron limitation in the Ross Sea. Glider observations were collected from Nov. 29 through Jan. 15 in a spatially restricted region in the southern Ross Sea during the annual phytoplankton bloom. Surface chlorophyll concentrations indicated that there were three stages: the first in which phytoplankton growth was large, resulting in a rapid accumulation of biomass; the second in which biomass remained relatively constant; and the third in which biomass in the surface layer decreased. Changes in particulate organic carbon in the water column were quantified, and the flux of carbon below 50 m assessed by mass balance. Fluxes were near zero initially, but increased through time, and were greatest during the last portion of the experiment. Iron limitation was determined using the recently developed fluorescence inhibition technique. It was determined that iron limitation became strong during the second and third portions of the study, and that it increased passive sinking rates considerably. Hence, the flux of organic matter and surface iron limitation are intimately connected and need to be considered within biogeochemical models of the Ross Sea.

SCAR 2020

Antarctic Science -
Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 44

CONNECTING LEGAL AND POLICY NEEDS WITH ANTARCTIC RESEARCH (INCLUDING RELATED TECHNOLOGIES AND LOGISTICS)

Akiho Shibata
Kevin Hughes, Daniela Liggett, Indi Hodgson-Johnston

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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SONIC: Schirmacher Oasis Nippon (Japan) India Coring Expedition: an Indo-Japanese joint effort

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The ice-free regions along the 18,000 km Antarctic coastline are marked with hundreds of freshwater lakes which are source to sedimentary archives from which past-climate can be reconstructed. Of recent, countries are pooling in resources with shared logistics, technology and scientific objectives to carry out collaborative projects. A joint effort was initiated during early 2019 between India and Japan. The objective is to work in the ice-free regions of East Antarctica viz., Schirmacher Oasis, East Ongul Island and Larsemann Hills involving India, Japan, Belgium and United Kingdom. This will help us to access major ice-free regions to generate a holistic output from East Antarctica. Our project is based on two fundamental objectives (1) those related to global change, and (2) those related to fundamental discoveries. The first phase of the project has been completed during 2019 Antarctic Summer (November-December) between India and Japan under the joint coring expedition SONIC (Schirmacher Oasis Nippon India Coring expedition). During this expedition, we collected sediment cores ranging from 1 m to 8 m from Schirmacher Oasis using a piston-corer modified and improvised by one of our team members. These sediments archives, which form a crucial link between the ice-cores and the marine sedimentary archives, are crucial in understanding ice-sheet dynamics, evolution of the ice-free regions, relative sea level variation and the general Antarctic climate. Here, we present how this group evolved, what we envisage and the expected output for East Antarctica from this collaborative effort along with a brief review of our field outcome.

1609

The New Zealand Antarctic Science Platform - a novel approach to support collaborative, high priority research and large infrastructure

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The purpose of New Zealand's Antarctic Science Platform (ASP) is to conduct excellent science to understand Antarctica's impact on the global earth system, and how this might change in a future world where global temperatures might be limited to the Paris Climate Agreement target of 2°C or continue to rise.

The ASP is designed to enable research focus and collaboration with a dedicated, mandated funding structure that provides long-term, stable funding for the New Zealand research community. The intent of the ASP is to support New Zealand researcher to lead or significantly contribute to research campaigns that are addressing the most pressing research questions, connected nationally and internationally, effective in supporting policy initiatives, future-proofed in terms of capacity building, and responsive to evolving research priorities and opportunities.

The ASP supports a mandated research portfolio that aligns to defined research priorities. Unlike competitive proposal structures, this programme has been developed using a negotiated approach. The research priorities have collectively been identified by the New Zealand research community, government agencies, stakeholders and end users in several workshops.

Key characteristics of the ASP include the integration of interdisciplinary and diverse research teams, the facilitation of expert groups on science to policy interface and on policy-ready projections and the continued review by independent international experts.

Early successes of the ASP suggests that such an approach strengthens the national research community, provides a strong foundation for international collaboration, supports the development of major infrastructure, and allows for effective capability building and succession planning.

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Norwegian interests and participation in the protection of the Southern Ocean

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Norway is an important player in Antarctic governance. As a claimant state with historic whaling interests, they have long held influence in decision-making. Today, Norway takes the largest catch in the Antarctic krill (Euphasia superba) fishery while also leading innovations in sustainable management. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) - a 26 member body (including Norway) which manages the Southern Ocean - has been moving towards adopting a network of marine protected areas (MPAs). Norway has been very influential in this effort – at times supporting and at other time opposing. Here, our research seeks to understand how Norwegian interests in Antarctica - including historic, political and economic - impact the adoption of MPAs. To complete this research, we performed a content analysis of Norwegian government documents and CCAMLR meeting reports combined with interviews with key informants. Norway has shown a complex combination of support and concern, many related to economic interests, the role of science, and Norway's positions in other global realms (e.g., the Arctic). A variety of themes emerged that help describe Norwegian positions and actions in the Southern Ocean MPA process: Norway as a leader in the Antarctic, and in global ocean sustainability; the importance of science which informs utilization and protection; Norway as a mediator in international cooperation; and the importance of The Law of the Sea Convention. Our research helps provide insight into Norway's positions and into understanding consensus in the CCAMLR MPA process.

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Enabling policy-makers to participate in and frame the science inputs to policy: the role of dialogue to inform simulation modelling used to evaluate the efficacy of risk management systems for Antarctic krill

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The approach to manage the localised effects of the krill fishery on krill predators being developed in the Scientific Committee for the Conservation of Antarctic Marine Living Resources aims to spread the local risks of the fishery across a region. This approach was first proposed in 2016, is considered to be a precautionary approach to managing localised effects of fishing, and provides opportunities to focus research and assessments in areas considered to be of higher risk to the ecosystem and/or of greater interest to the fishery. While this approach seems to be wholly scientific in providing advice to policy makers, there are opportunities, using qualitative as well as dynamic modelling, for involving stakeholders in deciding how best to spatially structure the fishery while spreading the risk. This presentation will detail the logic of the approach to spreading the risk of localised effects of a regional krill fishery, simulation methods to evaluate the efficacy of the approach under conditions of inter-annual variability and long-term ecosystem change, and a process for engaging with stakeholders on designing spatial fishing strategies that satisfy the requirement to spread risk.

1661

Antarctic Science from Political Realism: Why some countries have more robust Antarctic Program than others without consideration of their geopolitical size?

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The people involved in Antarctic scientific research, as in general terms the professional scientists do, make significant efforts to show themselves as a non-political and only-science-aims-interested community. The Scientific Committee on Antarctic Research (SCAR) is very concern about this independence. On the other hand, some States – with some relative independence of their geopolitical size– put a significant amount of money and all kind of resources to reach and maintain a relevant position on Antarctic affairs. In this sense, they use their National Antarctic Program as a diplomatic and political tool in their international relations. Which is true? The objectivity of the scientific personal or the political-oriented attitude of the States? Probably there is not a unique answer. Of course, scientific research needs some methodologies and procedures that must be not political-influenced to be able to make valuable contributions. However, that happens in a very political environment, as international Antarctic issues are. In the presentation, some aspects of the Antarctic Treaty System history will be analysed as well as the performance of some selected States in relation with their scientific programs, their investments in Antarctic equipment and facilities, and their influence in the Antarctic Treaty Meetings. What can tell us this complex performance in a time of geopolitical challenges?

1126

The effectiveness of the science – decision-maker nexus in an Antarctic context

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The interface between science and policy has been examined across a diverse spectrum of global issues, yet in the context of Antarctica, empirical research on this nexus is scarce. The continent and surrounding ocean hosts a range of human activities now increasing in scale, and the region is experiencing significant environmental change. The need for local, national and international policy action and collaborative global solutions has never been more pressing, and Antarctic science holds the answers to important questions related to global environmental change.

This paper closely examines and critiques the science - decision-maker nexus and assesses the 'effectiveness' of knowledge transfer within an Antarctic context. Drawing on a number of case studies, we further unpack what 'effective' science-policy engagement truly means. We explore stakeholder perceptions regarding the Antarctic science-policy interface, how research objectives are co-produced across scientific and policy communities, and whether models such as horizon scanning science and policy may contribute to a more effective knowledge transfer across a complex social boundary.

Findings from our internet survey carried out within the Antarctic community in 2016 suggest that distrust and miscommunication are present at the Antarctic science-policy interface. Based on this data and findings extrapolated from the case studies, including a critical analysis of the 'effectiveness' of the 2014 Scientific Committee on Antarctic Research (SCAR) Antarctic and Southern Ocean Science Horizon Scan's impact on policy outcomes, we argue that science becomes increasingly 'actionable' when co-produced by science and policy communities through an iterative, credible, salient and legitimate process.

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Assessing the policy impact of the Antarctic Environments Portal

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The Antarctic Environments Portal was launched in 2015. Its aim was to provide succinct knowledge summaries on issues of direct relevance to Antarctic managers and policy-makers. It was intended to provide a meaningful link between the ever-growing depth of academic literature and the lengthening list of issues facing the Antarctic management and policy communities, and provide support to policy discussions and (potentially) decision-making.

Five years after its launch and following the transfer of the Portal to SCAR in January 2020, it is timely to ask how successful the Portal has been in achieving its objective and what, if any, impact it has had within the Antarctic Treaty System.

An end-user survey conducted in 2019 generated 196 responses. Among respondents:

- 60% were first-time users
- 86% visited the Portal a few times a year
- 79% said that the clarity of content was good or excellent
- >80% agreed that the Portal articles were useful and reliable

38% of respondents recorded that they use the material to prepare for Antarctic Treaty-related meetings. Whilst these responses provide a strong sense of interest in the Portal, it is more challenging to assess the policy impact.

This presentation will review the outcomes to the end-user survey, outline some of the foreseen and unforeseen challenges that were encountered in securing policy support for the initiative, and outline future plans under SCAR's oversight including how the Portal can better support the work of the Committee for Environmental Protection, as well as other Antarctic policy stakeholders.

1523

A carbon neutral Antarctica should begin with science

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Given that the establishment of SCAR led to the Antarctic Treaty and the associated Protocol on Environmental Protection, science has driven many activities on the continent. The SCAR community, therefore, has an obligation to lead in all dimensions of environmental stewardship, including reduction of greenhouse gas (GHG) emissions generated by scientific and other activities in Antarctica. Here we present three recommendations for consideration by SCAR's Members and Delegates. First, solicitations for scientific funding (and associated annual and final reports) should require answers to the following questions from principal investigators: (a) Was the avoidance of nonessential GHG emissions considered in the development of the project? And (b) Are there technologies on the market, and/or synergies with other programs, that could reduce expected GHG emissions if they were available? Responses could be monitored by national operators and compiled by SCAR, to understand how fieldwork can be undertaken with net zero GHG emissions within the timeframes recommended by the IPCC. SCAR could report this information to the International Science Council, Antarctic Treaty meetings, and COMNAP. Second, funds solicited from conventional government programs, private foundations, and corporate philanthropy should be available to scientists and inventors with substantive, innovative proposals for platforms and approaches to minimize GHG emissions in Antarctica. Third, the scientific community must promote and incentivize environmental stewardship by selecting vendors and collaborators committed to carbon neutrality and climate justice. Antarctic science has contributed substantially to our comprehension of anthropogenic climate warming and its consequences, and we must be part of the solutions.

1164

Planning for Societal Impact: developing a system to ensure the Australian Integrated Marine Observing System delivers observations relevant to national and international Antarctic science priorities

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Australia's Integrated Marine Observing System (IMOS) is a national marine research infrastructure which has been collecting sustained ocean observations since 2006. Approximately 20% of that investment is made in the Southern Ocean region
Being a government-funded infrastructure, it is critical that the datasets collected ultimately deliver societal benefit. IMOS has a strategic approach to ensure that the ocean observations it invests in have a 'pathway to impact', i.e. that the science is linked to policies and legal frameworks that deliver benefits to society.
The strategic approach has included developing a systematic approach to surveying the social and cultural, economic, legal, political and policy environments; ensuring that national research partnerships, modelling communities, and operational partnerships are engaged in the process of investment and activity planning; that the broad and multi-disciplinary IMOS community are enabled to drive the use and impact of the datasets; and that the impact of the research derived from IMOS data are communicated across various platforms.
This talk will outline IMOS activities in the Southern Ocean, address the methods used, challenges faced, outcomes achieved, and reflections upon the strategic approach to planning for environmental, societal and cultural, and economic impact. IMOS will welcome the views of the SCAR and COMNAP communities as to how the approaches to planning for the greatest impact of ocean observations can be achieved, improved and/or enriched for the benefit of Australia's research-based ocean observing infrastructures in a Southern Ocean context.

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Enhancing science-policy communication to deliver the Committee for Environmental Protection's Climate Change Response Work Programme

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Climate change is one of the most important factors influencing the state of the Antarctic environment. Impacts on marine and terrestrial environments, and their biota, are becoming increasingly evident. A sound understanding of the climate challenges facing Antarctica, informed by high-quality science, is essential to enable appropriate environmental management actions.

In 2015, the Antarctic Treaty Consultative Meeting (ATCM) agreed the Climate Change Response Work Programme (CCRWP). The CCRWP identifies actions for the Committee for Environmental Protection (CEP) to support efforts within the Antarctic Treaty System to prepare for (i) the environmental impacts of a changing climate and (ii) the associated implications for the governance and management of Antarctica. To help with the efficient implementation of the CCRWP, the CEP established the Subsidiary Group on Climate Change Response (SGCCR) in 2017. This group is tasked with:

- facilitating the communication of the CCRWP, including identified science needs, to the Antarctic science community; and
- helping communicate relevant scientific research back to the policymakers within the Antarctic Treaty System.

This presentation will set out the key issues within the CCRWP, including climate change impacts on terrestrial, freshwater, marine and human (built) environments, key species vulnerable to climate change, and the effect of climate change on non-native species establishment and invasion. It will highlight specific research needed to help address environmental management issues, and encourage robust cooperation between policy makers and the Antarctic science community.

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Experience in investigating quantitative characteristics of the State Target Scientific-Technical Program (STSTP) execution efficiency for Ukraine's Antarctic Research for 2011-2020

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Nowadays the main quantitative characteristics of STSTP execution efficiency (e.g. samples number collected in Antarctic; developed mathematical models; scientific publications) are incomplete and insufficient to characterize STSTP for both stakeholders and the public.
The investigation proposes the methodology for the estimating of STSTP execution efficiency using the application experience, in particular, the Dow-Jones Industrial Average.
Instead of the shares value of most efficient companies, 25 quantitative characteristics of STSTP tasks and activities are offered, based on the application experience and practice of Antarctic Treaty System Institutions (ATSI) - SCAR, COMNAP and others.

Proposed characteristics are available on ATSI's and Ukraine's sites and characterize mainly Ukraine's cooperation with ATSI (e.g. amount of:
• Scientific-Technical Programs, Groups of ATSI with the Ukraine's representatives;
• Scientific-Technical Projects submitted by Ukraine's representatives to ISDA Work Programs;
• Scientific-Technical Products developed during STSTP realization and implemented in ATSI).
The methodology uses the normalized weight of the non-zero characteristics number at the analyzed year end as the STSTP Execution Efficiency Index (EEI). For example, if all 25 characteristics are non-zero, then the maximum value of the normalized weight of these characteristics - the STSTP EEI will be 1.
In practice, the STSTP EEI for 2016 is 3/25 = 0.12, for 2018 - 5/25 = 0.2.
The methodology is proposed for the new STSTP development for Ukraine's Antarctic Research for 2021-2025 and for consideration of the development possibility by SCAR the unified evaluation of the Antarctic Treaty Parties Research Programs execution efficiency.

1107

The important role of science in international efforts to protect the Antarctic environment

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Science and environmental protection are intimately linked in the Antarctic, as reflected by the region's international designation as a natural reserve, devoted to peace and science. The objective of the Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol) is to comprehensively protect the Antarctic, including its globally-significant scientific values. Explicit in the Environmental Protocol is a recognition of the need to draw on the best available scientific advice to understand the state of the Antarctic environment, how it is changing and is predicted to change, what is driving those changes, and what can and should be done to address them. The Environmental Protocol established the Committee for Environmental Protection (CEP) to provide Antarctic nations with expert advice on how best to address ongoing, new and emerging environmental challenges facing the Antarctic. The CEP relies on the best available and up-to-date knowledge in delivering such advice. The Scientific Committee on Antarctic Research (SCAR) is a significant and valued participant in producing and making relevant knowledge available to the CEP. This presentation will outline the CEP's priorities, detailed in a rolling five-year work plan that also identifies associated science, knowledge and information needs. It will also highlight the importance of continued close collaboration between the CEP and the science community, and the various avenues for science to inform international efforts to ensure the wise management and protection of Antarctica.

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Stakeholder engagement in decision making and pathways of influence for Southern Ocean ecosystem services

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Southern Ocean ecosystem management is characterised by a unique 'transactional landscape', relating to the globally significant services that these ecosystems support. This transactional landscape spans stakeholders from industry (fishing and tourism), governments, science, conservation non government organisations, civil society and international decision-making forums. We used a stakeholder mapping approach to provide the first description of the transactional landscape for Southern Ocean ecosystem management – both in terms of the connections between stakeholders and ecosystem services, and directly between stakeholder groups. We considered 65 stakeholders and their relationships to 12 provisioning, regulating, supporting and cultural ecosystem services. An analysis of the connections within this landscape reveals differences in the degree of connectivity between stakeholders and ecosystem services. Notably, ecosystem science facilitates high connectivity between stakeholders and provisioning services, but there is little connectivity between stakeholders and supporting services. We then applied a formal 'values-rules-knowledge' framework to a set of case studies to analyse the decision-making process in relation to Southern Ocean ecosystem services, as well as the relative importance of different stakeholder groups which were considered in the network analysis. Our analyses suggest that emphases for decision making have been on knowledge and rules, but that wider consideration of values across the broader stakeholder landscape – together with science (knowledge) and governance (rules) – might better support decision making for Southern Ocean ecosystem conservation and management, and provide a stronger foundation for sustainable provision of ecosystem services into the future.

334

Antarctic Data Analysis: Supporting the environmental management of Antarctica

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Providing the Antarctic policy community, the tools and knowledge to support environmental management is critical for both the health of the Antarctic environment but also the Antarctic Treaty itself. Manaaki Whenua has developed the Antarctic Data Analysis (ADA) tool to provide context to, and assist, the Antarctic Policy community in the planning, permitting, and implementation of Antarctic activities.

ADA eliminates the need for desktop geographic information system software or advanced technical expertise, by processing and presenting data in an easy to use way using analysis of spatially explicit data, such as: facilities, environmental management, biogeography, human activity, climate, and geology. A query-based approach to the tool, enables users to discover, query and visualise spatial and temporal data about how Antarctica is changing.

ADA, which has been developed with input from the Antarctic Policy community, was primarily built for environmental managers, and parties to the Antarctic Treaty and the Committee for Environmental Protection, but is expected to also be used by the science community and the general public. We expect that this tool will be utilised to enable the conservation of the Antarctic continent, and hope that new data will be included in the tool from the wider Antarctic science community to continue to close the gap between Antarctic science and policy.

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Celebrating the first 25 years of the European Polar Board, 1995-2020

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Throughout 2020 the European Polar Board (EPB) is celebrating its 25th Anniversary.

Established in 1995, the EPB currently includes 27 Member organisations from 19 countries, providing a combined authoritative voice for the European Polar research, logistics and policy communities, and the wealth of knowledge and expertise they represent. Current EPB Members include research institutes, government ministries, funding agencies, scientific academies, and polar operators from across Europe working at the nexus of Polar science, logistics and policy. Together, EPB Members focus on major strategic priorities in the Arctic and the Antarctic. The EPB's strong and independent voice comes from its Members, with and for whom it endeavours to coordinate, promote and advance European Polar research, supporting work to address Polar issues of global significance.

The EPB's major achievements at the confluence of Polar research, logistics and policy are numerous. They include coordination of joint Polar climate research calls, serving as the forum for the development of several large European projects, developing the European Polar Infrastructure Database and Catalogue, promoting greater coordination of Polar research with international partners, participating in major international projects such as the EU-funded SO-CHIC, and CHOICEe a collaborative project between the EPB and the European Space Agency.

The EPB celebrates the achievements of its first 25 years while going from strength to strength, looking ahead to many more successful years coordinating, promoting and advancing the European Polar research community.

For more information on the EPB and its 25th Anniversary celebrations, visit www.europeanpolarboard.org.

1504

New Zealand’s Antarctic Science Platform: A collaborative approach

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Antarctica New Zealand hosts a government-funded “Antarctic Science Platform” - a long-term (7-year) strategic investment in Antarctic research. This investment in New Zealand’s Antarctic research programme has provided a more co-ordinated approach to addressing science priorities and builds on New Zealand’s existing Antarctic research strengths. The Platform specifically aims to facilitate enduring international collaborations, align research effort with policy needs, foster innovation through multidisciplinary collaborations and technology development, incorporate indigenous (Māori) knowledge, and integrate planning for science and logistics needs.

Research priorities focus on understanding Antarctica’s impact on the global Earth system and how this will change in a warming world. This paper highlights the aims of the Platform, outlines the planned research programmes, and describes opportunities to develop science and logistics collaborations with other national Antarctic programmes. It illustrates how expert groups focused on the science-policy interface and future projections are integrated across the programme, and how Research Fellows, in a centralised Modelling Hub, contribute their expertise across a broad range of research areas.

The Platform’s intent will be fully realised when New Zealand researchers are leading campaigns that address the most pressing research questions, are better connected nationally and internationally, are effective in supporting policy initiatives, are future-proofed in terms of capacity building, and are responsive to changing research priorities and opportunities.

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Pogo-sticking across Antarctica: why celebrity "science' is not the answer

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There is a complex nexus between science and policy. Good policy needs to be based on a solid foundation of fact, analysis and critical thinking. Good policy also requires a clear and achievable path to implementation. Matching science with aspirational policy, and informing the critical path to achievement, is often fraught - and sometimes vexed.

The outline of SCAR session 44 states (in part) "Perhaps, we ought to think of more innovative means [to link science and policy], including strategies drawing on the concepts of advocacy and ambassadorship in relation to Antarctic issues and possibly involving high-profile scientists and famous celebrities".

This presentation will explore the role of activism, policy populism, celebrity intervention, and environmental outcomes in the Antarctic from the Minerals Convention to the current day.

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Towards an effective reciprocal communication between the Antarctic science community and policy-makers

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Globally, the science-policy interface is perceived as very complex. The social processes that take place between scientists, policy-makers and other relevant actors to develop effective policy are often misunderstood, and the slow and lengthy progress may discourage those involved. In the Antarctic context, the Antarctic Treaty System (ATS) and the Scientific Committee on Antarctic Research (SCAR) represent the main science-policy collaboration. Yet, amid the growing threats to Antarctica's environments from global and local anthropogenic impact, further engagement and stronger ties across the science and policy-making community are needed to keep pace with the management challenges faced by the ATS.
Currently, little is understood about (a) the two-way interaction between Antarctic scientists and policy-makers, (b) the extent of efforts by Antarctic researchers to engage in the policy-making process, and (c) how policy-makers seek input from polar science experts. In this paper, we address the main issues Antarctic stakeholders face in maintaining effective reciprocal communication between the science community and policy-makers. We present a preliminary analysis of twenty-four interviews that were conducted in 2016 with leading Antarctic scientists, managers of Antarctic agencies and senior advisors to those responsible for polar governance. Finally, we highlight the lesser-known constraints of the Antarctic science-policy interface, and elucidate ways to improve effective communication between actors. Reaching an effective reciprocal level of communication between the science and policy-making stakeholders will enhance and encourage mutual collaboration to best support an informed, effective decision-making process to manage Antarctica.

1373

Antarctic governance and conservation: Global lessons in the Anthropocene

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In the age of the Anthropocene, Antarctica is a model system for understanding climate change, human impacts and the potential of conservation science. Recent research and large-scale social activism highlight that climate anxiety, and general anxiety about the future of the planet, are increasing. Amidst narratives about the failures of global leadership (e.g., COP25) Antarctica provides a beacon of global diplomacy, scientific collaboration and environmental stewardship. In short, Antarctica offers lessons and hope for the future.
We present a case study of how an in situ program featuring Antarctic conservation and governance can inspire an international multi-disciplinary STEMM audience to become leaders in the Anthropocene. The project is a year-long women's global leadership initiative, culminating in a three week Antarctic expedition. Thus far we have trained more than 400 women from 38 different countries. Combining Antarctic conservation and governance lectures, round table discussions and experiential site visits enable women to learn in Antarctica. We highlight Antarctica as the global early warning system for climate change. Women experience Antarctica, being humbled and inspired by its scale, beauty and extremes. We explore governance and policy challenges to global sustainability. Antarctic governance and policy is presented as novel paradigm for successful conservation and science diplomacy. As a core group of Antarctic scientists we showcase outwardly the global significance of Antarctica, to ensure continued protection, and promote greater support for Antarctic science resourcing.
Our innovative in situ classroom has empowered 400+ new advocates for Antarctica conservation and promoted a new inclusive model for governance.

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Using the best available science to inform policy and management decisions in Australia

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The importance of scientific cooperation was recognised in the negotiations of the Antarctic Treaty, and has been central to the success of the Antarctic Treaty system over the past 60 years. While science alone cannot provide the answers, policy and management decisions are more robust when they are informed by the best available science. In a place as harsh and remote as Antarctica, the concept of the best available science is critical. Equally important is the need for scientists, policy advisors and decision makers to bring their expertise together to work collaboratively to uphold the principles of the Antarctic Treaty system, including protecting and conserving the Antarctic and Southern Ocean environments. In this presentation, examples will be provided on how scientific research has been used to inform policy and management decisions in Australia, contributing to our engagement in the Antarctic Treaty system, and in our domestic implementation of our obligations arising from the system. It will also discuss the challenges currently facing policy advisors and decision makers and the role that scientists can play.

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The policy relevance of Southern Ocean food web structure: Implications of food web change for fisheries, conservation and carbon sequestration

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Southern Ocean food webs provide ecosystem services with significant global value including carbon sequestration, fisheries and the existence of iconic wildlife. These services are underpinned by different energetic pathways including those dominated by Antarctic krill, fishes and squids, or gelatinous zooplankton (salps). Climate change is likely to impact Southern Ocean food webs by affecting their foundations — both primary producer communities and ice habitats. However, the implications of these changes for ecosystem services – including wildlife populations, fisheries and carbon sequestration – are unclear, as are the implications for policy and management. We used a generalised representation of Southern Ocean food webs and qualitative network modelling to investigate the consequences of five simple but plausible scenarios of future change for ecosystem services and the conservation of important taxa: (i) a shift in primary producer communities with decreasing large diatoms and increasing small flagellates; (ii) increasing salps; (iii) increase (recovery) of the Great whales; and unregulated and unsustainable fisheries for (iv) krill or (v) toothfish. Strikingly, our results suggest that increases in salps might not have negative consequences for ecosystem services and could enhance carbon export potential. Simulated increases in unregulated krill and toothfish fisheries affect predatory wildlife and could also reduce carbon export potential. Our results emphasise the important policy implications of understanding the structure and change of whole food webs, and highlight that improved quantitative understanding and modelling of the relative importance of different energy pathways will be important for developing robust management responses to climate change impacts.

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Coordination among decision-making processes within the ATS

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The purpose is to analyze how domestic and international decision-making articulate, both politically and legally, within the framework of the ATS.

This analysis is pivotal to forecast the capability of response of the ATS, at the level of its parts and the system, before any given issues concerning it, specially considering the global effects of Climate Change,both in the planetary and human systems, in the decades to come.

We´ll analyze the concept of resilience from a systemic perspective, with the objective of defining the processes, dimensions and known results. This will allow us to project into the future new scenarios based on expected results.

This fist analysis will be developed from three different approaches:

1. Leading cases of proven violations of the regulations of the ATS, focusing the processes that triggered conflicts and the interagency and international frameworks that guided its resolution.

2. Marine protected areas (MPAs), focusing on how domestic or bilateral issues are then presented on the ATS multilateral level.

3. The policy and decision making in of the operational tasks of the Joint Antarctic Naval Patrol of Argentina and Chile; and the use of the military forces in Antarctica.

This paper does not aim to arrive at definitive conclusions, but to carry out an inductive work that will result on a matrix of analysis, in order to gather institutional memory and jurisprudence that can be applicable in the future.

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Bringing Māori knowledge and philosophy to Antarctic science, policy and governance.

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Indigenous worldviews and knowledges offer alternative ways to think about the human relationship with the earth and can help to develop novel solutions to climate change and the global enviornmental crisis. They can also highlight assumptions and blind spots inherent in contemporary approaches to environmental management that may limit our ability to mount effective responses to the crisis. Our research focusses on how Māori worldviews and mātauranga Māori (Māori knowledges and philosophies) could be brought into New Zealand's Antarctic science, policy and governance. Our research approach sought to engage Māori communities across New Zealand in conversations about their aspirations for representation in Antarctica, how they could approach achieving those aspirations, and the research that needs to be done to inform those approaches. To support our conversations, we examined existing national and international models in which Indigenous voices, knowledges and worldviews are represented in contemporary environmental management around the world. We identified strengths and weaknesses in implementation as well as in the process of their development and negotiation. Our research seeks to bring equitable Māori representation into New Zealand's Antarctic science, policy and governance, and to raise the standard to ensure Indigenous peoples are equitable partners in research projects designed to support their representation in environmental management.

SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 45

INCLUSIVE COLLABORATIONS IN ANTARCTIC RESEARCH

Renuka Badhe
Morgan Seag, Alex Thornton, Iqra Choudhry

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Toward inclusive collaborations in Antarctic research: understanding intersectionality

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Scholars and practitioners working on diversity, inclusion, and equity are increasingly recognizing the importance of intersecting issues affecting individuals as a sum of more than their parts. Intersectionality in this context refers to the ways in which multiple forms of disadvantage and discrimination (including and beyond sexism and racism) can be compounded, creating unique obstacles (or opportunities) for certain groups and individuals.

This talk applies the concept of intersectionality to ongoing efforts worldwide to create more inclusive and equitable Antarctic research communities.These challenges may be related to sex, gender identity, sexuality, socioeconomic status, language, nationality, religion, disability, ethnicity, race, age, familial and caregiving responsibilities, and/or other factors. Understanding the ways in which barriers associated with these categories intersect, and the implications of that process, is an important and powerful tool in making communities more inclusive - including Antarctic research communities. Both Antarctic collaborations and research are broadly poised to benefit from a tremendous diversity of ideas and approaches if we as a community can fully commit to understanding and addressing overlapping, interconnected barriers to equality and progress in our fields.

In this light, this talk:
1. Introduces the concept of intersectionality;
2. Explores central tenets of the concept within Antarctic research, considering the international, interdisciplinary, collaborative context in which Antarctic research is often undertaken;
3. Discusses the value of intersectionality as a methodology for Antarctic Humanities and Social Sciences research;
4. Discusses the value of intersectionality as a tool for Diversity, Equality and Inclusivity within the broad context of Antarctic Institutions.

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Taking responsibility for the assumptions and shortcomings of our specialized disciplines within interdisciplinary efforts.

Larelle Bossi[1]
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Inclusivity is an ethical position. Inclusivity as an ethical position is saying yes to the other. Yes in the acknowledgment of the Other. In this presentation I address the necessity in acknowledging, sharing and overcoming the assumptions and limitations we each present as representatives of diverse and specialised disciplines within interdisciplinary discourse. Prior to even delivering research for policy-making, the conceptualization and formation of explicitly crafted interdisciplinary research requires the synthesis of multiple fields of expertise. Seeking out communications concerning the governance of Antarctic socio-ecological systems ought not be a mere afterthought or puzzle post-data collaborations. Rather, the 'human dimensions' precede the scientific hypothesis and necessitate/postulate the 'coming together' of all disciplines involved prior to any field work and analysis at all. The socio-ecological systems within the Antarctic environments are themselves the human enterprise. The governance and human dimension of these Antarctic socio-ecological systems therefore are not separate from science, but an integral dimension of it. This presentation considers a conceptual framework of interdisciplinary discourse which never abandons the human dimension in Antarctic research and governance. Inspired by philosophical forms of critical thinking, it hints at methodological approaches toward effective ways in which to engage with each other.

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Opportunities for Early Career Researchers in Antarctic Science, the perspectives and priorities from the Association of Polar Early Career Scientists and the Marine Ecosystem Assessment for the Southern Ocean

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Involvement of Early Career Researchers (ECRs) in international scientific collaborations provides invaluable experience and training for individuals aspiring to become future researchers and leaders in science. In Antarctic research, various organisations and initiatives create these opportunities through supporting and promoting contributions from ECRs. Here we focus on ECR opportunities arising from the linkage between the Association of Polar Early Career Scientists (APECS) and the first Marine Ecosystem Assessment for the Southern Ocean (MEASO). We review the benefits to ECRs from their involvement in the MEASO process, from the organisation of the MEASO international conference held in 2018, participation in developing and reviewing information pages on Southern Ocean biota on the Southern Ocean Knowledge and Information (SOKI) wiki, to lead and co-authorship of manuscripts to be published as part of the special issue reporting on the outcomes of the assessment. We discuss the motivations of ECRs participating in initiatives such as MEASO in conjunction with PhDs and other research commitments and the various obstacles currently facing ECRs that limit their capacity to pursue such opportunities and future career pathways. We incorporate the outcomes of the APECS ECR workshop held prior to the SCAR 2020 conference held in Hobart, suggesting strategic actions that could potentially be implemented by ECRs within challenging research environments and perspectives on emerging future priorities for Antarctic research.

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The Role of APECS in SCAR & the Polar Sciences

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The Association of Polar Early Career Scientists (APECS) is an international and interdisciplinary network for undergraduate and graduate students, postdoctoral researchers, early career professionals, educators, and others interested in polar and alpine regions and the wider cryosphere. The existence of APECS as a stakeholder in the last decade has been fundamental towards developing a diverse future leadership in the polar research community. APECS has grown from a small group established during the 2007/08 International Polar Year (IPY) to a global community of more than 3,200 actively-engaged early career researchers (ECRs) interested in all natural and social science disciplines focusing on the polar and alpine regions and greater cryosphere, from over 70 countries. APECS aims to continue growing and providing opportunities for polar ECRs around the globe through capacity building, being on the cutting edge of information assessment, and education and outreach. I will discuss recent initiatives and activities by APECS in cooperation with SCAR while I have been a member of the Executive Committee, as well as how we can we further integrate diversity, equity, and inclusion (DEI) principles into our agreements and meetings.

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University of Concepción Antarctic and Subantarctic Science Program (PCAS), Chile.

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Antarctica is a continent rich in natural resources that contribute to knowledge and biotechnological development and an important regulator of the planet's climate. Recently it has shown its fragility and vulnerability to global climate change. The registration of plastics and hazardous chemical residues in the Antarctic Ocean and non-native species in their terrestrial and aquatic ecosystem, reflect human activity. Meanwhile, the Sub-Antarctic region represents a crucial element in understanding the trajectory of polar ecosystems in the face of growing anthropic pressure. Chilean Patagonia, one of the largest fjord ecosystems in the world, has a rich biodiversity and influences the hydrography and biogeochemistry of the Eastern South Pacific Ocean. Chile, due to its geographical proximity to Antarctica and for having scientific bases in Antarctica and Sub-Antarctica, has a strategic position to conduct global research. The Universidad de Concepción has a long history of research in both regions, reflected in the significant number of researchers, projects and publications with national and international appreciation. The Antarctic and Sub-Antarctic studies integration with a multidisciplinary approach could improve the understanding of the changes trajectory of these ecosystems that are strategic for Chile and of global relevance. The creation of this Program represents a great opportunity to generate multidisciplinary research that is reference in Antarctic-Sub-Antarctic science at national and international level. The main goal of the Program is to grouped a multidisciplinary researchers team, and enhance active participation in research, diffusion and technology transfer projects in Antarctic and sub-Antarctic science and increase national and international collaboration.

1225

CCAMLR Scientific Scholarship Scheme: an important tool to involve early career researchers in CCAMLR processes and to build capacity

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The word 'inclusion' is widely used to refer to the overcoming of practical and conceptual boundaries that can occur in various areas. One significant boundary in the scientific community today that requires concerted efforts to be surmounted is the difficulty that early career researchers (ECRs) confront in order to get involved in high-level research and management systems. To overcome these obstacles, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) established the CCAMLR Scientific Scholarship Scheme in 2010 in order to promote the participation of ECRs in the work of the Scientific Committee and its working groups. The CCAMLR scholarship represents a way to engage enthusiastic ECRs in CCAMLR meetings and processes, with the objective to contribute to capacity building within the CCAMLR scientific community.

The CCAMLR scholarship program pairs recipients with a mentor from a different Member country who is available to guide the recipient through the processes and procedures of CCAMLR. In the last two years seven ECRs from Brazil, Italy, Germany, Argentina, Ukraine, Uruguay and China received the scholarship. Recipients represent diverse skills and interests: krill and whale distributions, non-extractive monitoring systems, fish and penguin population monitoring, krill ecology and krill larvae abundance and distribution. Such a comprehensive suite of competences serves to improve the exchange of capacity within the ECR community. Connections forged at the ECR level nourished by intra- and inter-generational dialogue among researchers strengthens the relationships between Member countries involved in the conservation of the Antarctic marine living resources.

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Diversity (humans) in Polar Science...

Donna Frater[1]
[1]UK Foreign and Commonwealth Office / British Antarctic Survey, , United Kingdom

Scientists study every element of the natural world we can reach, from the smallest animals in the depths of the oceans to particles in the Stratosphere. Some of the fields of science that the STEM students who are studying now will investigate, do not even exist yet. There is not a typical STEM job but there is a 'STEM stereotype' that society learns, and for Polar Science in particular, there is a gender and racial stereotype of a Polar Scientist, which resonates as an older, bearded, white male. This stereotype severely impacts who looks at polar science and who connects with the vital research done there.
If the collectors of these finding are all a narrow segment of the world's population how can you expect the polar science voice to influence change across a diverse planet?
The competition for the brightest, most innovative minds in the global STEM landscape is very strong. If Polar Science is going to attract the bright minds it needs, it needs to change its image and make a commitment to be more welcoming and embracing of diversity and innovation.
Lack of diversity limits innovation and limits the relevance to a broader group of people. If you do not have diverse scientists you do not have the point of view of particular life and cultural experiences of that person being represented. You are constrained by a select view of the world from people with a limited to exposure to a great deal of the planet.

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UK Polar Horizons project- Bringing diversity into Polar Science

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In recognition of the lack of diversity in UK polar science, inclusion initiatives and a research project were sponsored by the Foreign and Commonwealth office in 2020.
The UK Polar Horizons project, completed in March 2020, provided early career STEM students, an opportunity to experience research science in a polar context. The poster will detail how British Antarctic Survey opened its doors to postgraduate STEM applicants from underrepresented groups (LGBTQ+, BAME and people with disabilities) to experience what it's like to work in polar science. The STEM applicants were paired according to a science/engineering match and spent several days working side by side with their host and gathering an in depth look at polar research and operations.
The graphs of UK polar science diversity statistics compared to UK higher education statistics show the considerable gap in attraction. Polar science has failed to connect with and attract students from across the UK society and reflects that lack of diversity in its scientists. References to global polar organisations reflects the same lack of diversity and connection with a global audience.
We will have discussion and feedback graphics that evolved over the project week discussing outcomes and opportunities. Word cloud exercises show the development of the students understanding of polar science and its place in global policy making. Social media extracts will be used to show the early career researchers views of the project and polar science. Images on the poster, very clearly show more diversity than generally found in polar science gatherings.

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Your way to research at Neumayer Station III, Dronning Maud Land

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The German research station Neumayer Station III is located at 70°38’S, 8°15’W on the Ekstroem Ice Shelf. The location offers unique opportunities to study coastal Antarctic processes, ice shelf dynamics and marine life. A small group of seals and a penguin colony settle on the sea ice in easy reach approx. 10km distance to the station. The geomagnetic position of the station (L=4.2) is ideal to study ionospheric and geomagnetic phenomena. Long term observations of the air chemistry, meteorological and geophysical observatories can provide long time series of data and aid in answering project related research questions.
Additionally, Neumayer is a logistical hub for deep field campaigns in the hinterland and for the summer station Kohnen 800km south on the Antarctic plateau.
The station is open for other researchers in a transparent user application processes with external project reviews. Here we display the application process, the logistical and technical facilities of the station.

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Pride in Polar Research

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Inclusivity, equity, and diversity benefit all of Polar research, helping the community to realise its full potential. Pride in Polar Research (PiPR) was established when an early career researcher reached out to the community ahead of the POLAR2018 conference in Davos, seeking solutions to the isolation and discrimination issues they faced as a queer and intersex scientist. What began as plea to other members of the community to be more visible by wearing rainbow badges quickly developed into a group actively working to combat biases through community development and education. PiPR is inclusive, welcoming all Sexual Orientations, Gender Identities, Gender Expressions and Sex Characteristics identities (LGBTQIA+ and others). Since the first meeting in Davos, attended by >30 conference participants, PiPR has received support from SCAR, IASC, and other organisations, established Twitter (1400+ followers) and Facebook (200+ followers) accounts, and a moderated mailing list (100+ members), becoming an internationally recognised network.
PiPR is working to establish a more formal structure and is cooperating with Women in Polar Science, Minorities in Polar Research, other intersectional groups and allies across academia to build on its initial successes. Beyond supporting, connecting, and raising the visibility of members of our community, PiPR will produce resources intended to improve equity, diversity, and inclusion within Polar research. One priority is to provide practical advice to individuals and groups organising workshops, conferences, fieldwork, etc., on how best to be as inclusive and welcoming as possible, given the many different barriers that members of the PiPR community face worldwide.

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How the Association for Polar Early Career Scientists (APECS) Encourages Diversity and Inclusion Within and Beyond our Organization

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The Association for Polar Early Career Scientists (APECS) works towards a future where one's identity is not a barrier to success in polar science. In 2018, APECS introduced a project group on Diversity, Equity, and Inclusion (DEI). Their goals were to: (1) encourage and facilitate international, interdisciplinary dialogue about DEI topics in polar research, (2) provide resources for APECS members facing identity-related challenges, as well as for allies and leaders in our community, and (3) promote DEI principles within the structure of APECS and related communities, now and in the future. In practice, they facilitate discussion and action related to DEI issues to ensure APECS supports all members in their professional endeavors regardless of nationality, ethnicity, religion, race, sex, gender identity, sexual orientation, economic class, disability, physical appearance, age, or career status. This project group is structured as an umbrella group that provides guidance for APECS International Council members to lead activities related to the issues that are most important to them. Activities may focus on a single, narrowly defined issue (e.g. organizing a webinar to address misconduct in the field) or on a broad issue (e.g. generating a network of mentors). In their first two years, their achievements include (1) launching a curated online DEI resource repository on the APECS website; (2) hosting three webinars, permanently archived, on promoting inclusive policies, improving field conduct, and addressing bias in professional relationships; and (3) creating a network of mid to late-career researchers with DEI experience available as mentors to APECS members.

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The Diversification of Antarctic Science: A Historical Case Study from the McMurdo Dry Valleys

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The McMurdo Dry Valleys offer a useful case study for thinking about the diversification of Antarctic science over time. Since the late 1950s, this predominantly ice-free region has been an important centre for scientific research in Antarctica. Scientists from the United States, New Zealand, Japan and a number of other countries have conducted research here giving the region a strongly international history. At the same time, the distinctiveness of the Dry Valley environment helps to make it a discreet, bounded region which is helpful for historical analysis. This paper combines archival research and oral history interviews with a social network analysis of the scientific papers published on the McMurdo Dry Valleys since the early twentieth century to look at histories of race, gender, and class in Antarctic science. It considers ways that diversification in Antarctic science can be measured and looks at some of the obstacles to increasing diversity. While significant progress has been made in terms of gender diversity among the scientists working in the region, by some measures ethnic and racial diversity has decreased over time, suggesting that we need to be careful about narratives of linear progress. The paper concludes by thinking about how a historical approach might inform current efforts to diversify Antarctic science and considers how the McMurdo Dry Valleys case study might fit with the broader picture of Antarctic science as a whole.

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Looking ahead to the next U.S. Antarctic program multidisciplinary deep field camp

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The U.S. National Science Foundation has a history of deploying Earth Science focused deep field logistics hubs in the Transantarctic Mountains. To begin the process of planning for the next camp, a meeting of U.S. Antarctic researchers was held in October 2019 to identify geographic regions that are best suited to address top scientific priorities for the geological, biological and cryospheric sciences. Five regions were discussed and northern Victoria Land and the southern Transantarctic (Scott Glacier region) were ranked highest for their multidisciplinary research potential. Northern Victoria Land, adjacent to the Wilkes Subglacial Basin, is well situated to evaluate terrestrial records of Neogene-Quaternary fluctuations of the East Antarctic ice sheet, with regional and with global significance. The region would also provide opportunities to further explore such topics as geodynamic processes controlling volcanism and landscape evolution, latitudinal gradients in biodiversity (Paleozoic to Modern), Antarctica's role as a keystone continent in Gondwana, etc. Many similar objectives would be achievable from Scott Glacier. We welcome dialogue about potential collaboration and cooperation with other international programs.

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The Women in Polar Science Network: beginnings, progress and future directions

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Polar research and exploration has been historically male dominated, and the pathway of women in polar research over the past 70 or so years has entailed many women breaking one "ice ceiling" after another. The Women in Polar Science (WiPS) network started in December 2013 with the aim of connecting and supporting women working in Antarctic and Arctic research. WiPS has grown from a small grassroots network, to bring together 4000+ individuals across several social media platforms from all continents of the world. Across the network, women researchers are sharing their own experiences, struggles and stories, and highlighting their contributions to global science. WiPS have organised several major events since 2014, including networking events, a Women in Antarctic science Wikibomb to increase wikipedia profiles of female Antarctic scientists, and panel discussions on life experiences of women in polar research and leadership. To maintain a network as successful as WiPS, organising both events and communication on social media, relies on volunteer time and very little sponsorship. WiPS hopes to continue for many years to come, with a shared aspiration for a bright and inclusive future for polar research, supporting a diverse global community of researchers, and helping them thrive and achieve to the best of their potential.

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The power of networks to support diversity in polar research

Renuka Badhe[2], Emily Choy[3], Premdeep Gill[4], Huw Griffiths[4], Charlotte Havermans[5], Mary-Anne Lea[6], Jess Melbourne-Thomas[1], Joseph E Nolan[2], Stephen Roberts[4], Justine Shaw[7]
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Polar research is intrinsically global, intersecting with a range of societally relevant issues. Yet, Polar research has historically been dominated by generations of ethnically white men from European backgrounds. In the past, minorities that worked in these subjects were isolated by circumstance, geography and limited opportunity. As diversity within Polar research fields has increased, various networks including Women in Polar Science, Minorities in Polar Research and Pride in Polar Research have emerged from a growing understanding that the Polar research community should reflect society as a whole. It is widely understood that having a diversity of ideas and approaches, by supporting an increase in diversity of researchers, benefits research teams and outcomes, as well as research progress more generally. These growing networks, which include thousands of followers, voices and contributors, represent those who may not have been heard before, and can thus provide a platform for positive change. These networks rely on individuals, or teams of volunteers to enhance the visibility of underrepresented and marginalised groups in STEM, while highlighting the barriers and challenges they still face. Digital endeavours such as the women in Antarctic science Wikibomb event at the SCAR OSC 2016 demonstrate the power of people and technology to make a positive difference. In this digital age, underrepresented and minority groups have truly harnessed the power of the internet and social media to come together in support of diversity, equity, and inclusion in Polar research.

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Drawing Lessons for Including Women and Africans in Polar Research from a study on Women in Science in Africa

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The challenges that women in science struggle with are systemic institutional difficulties that contribute to them opting out of pursuing careers in science. We use science to collectively include science, innovation, technology, engineering and mathematics.These hurdles include inequality in remuneration, slower career progression, fewer leadership opportunities, sexual harassment, slower uptake of funding opportunities, amongst others. Despite progress in narrowing the gender gap in science in Africa, the scarcity of women in science research and careers remains stark. Equally stark is the under representation of women and African scientists in polar research. An African Academy of Sciences study on women in sciences that looks at the barriers women face, and the policy options that can support women in science in Africa. This paper will look at this study on women in science and the barriers it identifies, and the policy options it proposes, to draw lessons for building a more inclusive and representative polar research community, that is inclusive of women and Africans. The study proposes that policy options should begin by addressing the root causes, then move to develop strategies that will influence cultural orientations and stereotypes at all levels and finally develop interventions to ensure comprehensive support structures are in place to build a condusive environment for women and Africans (and other grouping) to undertake polar research.

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Gendered Power Relations and Sexual Harassment in Antarctic Science and Remote Fieldwork in the Age of #MeToo

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Antarctica is a remote, historically masculine place. It is also a workplace, and the human interactions there are connected to power structures and gendered expectations. Today, nearly 60% of early career polar researchers are women (Strugnell et al. 2016). However, women in Science, Technology, Engineering, Mathematics, and Medicine (STEMM) are 3.5 times more likely than men to experience sexual harassment during fieldwork (Clancy et al. 2014) making questions of safety, power, and harassment pertinent. Gender equity initiatives coupled with #MeToo have provided new platforms for reporting sexual harassment and challenging problematic research cultures which position science as meritocratic and gender-neutral. Yet, the impact of #MeToo in Antarctic science is uneven. The termination of Prof. David Marchant is widely cited as evidence that #MeToo is positively affecting Antarctic science. We argue it is problematic to focus on individual cases at the expense of the wider culture. We examine the complex historical (e.g. gendered interactions with the Antarctic landscape), cultural (e.g. identity politics), and relational (e.g. gendered power dynamics) tensions underpinning recent #MeToo revelations in Antarctic science with a view to providing more nuanced approaches to structural change.

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An APECS initiative to foster multidisciplinary collaborations between Polar Science and Art

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The Association of Polar Early Career Scientists (APECS) is the largest international network of early career researchers (ECRs) working in the high latitudes and the cryosphere. For over ten years, APECS has provided a platform for sharing ideas and providing training and skills development for ECRs with the aim of shaping the future generation of polar leaders. Polar education, communication and outreach have driven APECS activities since its inception in 2007 (Hindshaw et al., 2019).
ECRs value the importance of communicating science beyond academia. However, there is little formal preparation on science communication during ECRs' formative academic years, resulting in poor understanding of the skills needed, the tools available and the opportunities for collaboration with other disciplines. Art, in its many different expressions, can be an effective ally to science communication. The APECS Art Group aims to inspire ECRs to engage in art-science interaction by creating an online platform containing training tools and useful information to establish initial contacts with artists. Webinars by artists inspired by the Polar Regions, a Polar Art blog that highlights the collaboration between artists and scientists, and a comprehensive dataset of artists who are willing to or have worked with scientists in the Polar Regions will be made available to ECRs. This poster demonstrates examples of creative art-science collaborations within APECS and invites feedback and contributions from others with expertise in these fields.

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Gender in Polar Research – Reflections of the ASSW 2020 Workshop

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Gender in Polar Research – Gendered field work conditions, epistemologies and legacies has been the theme of the IASC funded workshop organized by the IASSA Working Group Gender in the Arctic, IASC's Cryosphere, Marine, Terrestrial and Social Sciences and Humanities WGs during the Arctic Science Summit Week (ASSW) in Akureyri, Iceland, 29–30 March 2020. This poster reflects the key discussions, statements and outcomes from presentations and interactive as well as artistic formats. The workshop combines three strands of debates: (1) Doing science in the 21st century in a way that departs from but also pays careful attention to the history of exploration and colonial endeavors as "heroic" and masculine activities – while a masculine image still seems to dominate the methodologies and practices of Arctic and Polar research. (2) The still existing gender gap when it comes to female researchers in hard sciences, their career prospects, and their sometimes difficult working conditions. Critiques of the gender gap has far neglected the diversity aspects of queer and gender minority (LGBTQI) researchers. They face particular challenges while working in a still largely heteronormative research environment as it is described for research stations, vessels or tundra/taiga camps. (3) The gendered composition of researchers as actors and the gendered spaces of conducting research, including the field sites, have an important impact on research interests, research design, research ethics and epistemology.

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SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 46

PUBLIC ENGAGEMENT WITH ANTARCTICA IN A CHANGING CLIMATE

Rebecca Priestley

Heidi Roop, José Xavier, Rhian Salmon

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Using grand scale media to drive conservation: Protecting the Last Ocean and beyond

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Antarctica is exceptional. The coldest, windiest, iciest, driest, and most remote of continents is widely celebrated for its rich history of exploration, science and diplomacy and for its exceptional beauty. It's also exceptionally important and vital to Earth systems and harbors some of the last remaining great wildernesses on the planet. However, fishing pressure combined with cumulative impacts of climate change, jeopardizes the future Southern Ocean wildlife. Extensive research supports that protected areas – areas that are off-limits to fishing and other human activities – can conserve biodiversity, and perhaps most importantly in the case of the Southern Ocean, can enhance resilience to climate change impacts.

Here we present on how we've used media to bring this exceptionally beautiful and important place to the public and to the policy-realm in support of designating large-scale Southern Ocean MPAs. Our story starts with the 12-year long Last Ocean project which helped drive the adoption of the Ross Sea region marine protected area in 2016. We share stories and lessons learned for effectively working at the intersection of science, policy and the public. We highlight the powerful role that media can play in creating an intimate experience between the public and the most remote of continents. Finally, we end with recent efforts to use grand scale media in targeted countries (e.g., massive outdoor photography displays in Russia) to continue to promote the adoption of large-scale Southern Ocean marine protected areas.

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Beyond the Heroic Age of Exploration: Fusing Environmental Literature with the New Human Experience South of 66°33’48

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Publicly available sales figures suggest that trade books in which Antarctica features centrally have yet to achieve enduring commercial success beyond those set in the “Heroic Age of Antarctic Exploration,” approximately 1897-1922. A trade book is defined as one written for a general readership (i.e. not academia). Of the 100 United States bestsellers in March 2020 in the nonfiction subcategories of “environment and nature,” “climatology,” and “environmental policy,” Amazon reports that none focus on Antarctica. (The United States is the largest publishing market in the world. Amazon is the largest bookseller, accounting for 41% of all books sold.) A February 2020 public opinion poll conducted by Pew Research Center suggests 52% of Americans call climate change the top issue for the next U.S. president—up 14% since 2016, and the first time a majority of Americans rank climate change as the top presidential priority. With increased coverage of Antarctica and the effects of climate change, the lack of interest in Antarctica-related books is crosswise with the cultural zeitgeist. The disconnect between growing popular concern about the environment and poor Antarctica-related book sales is attributable partly to a rigid adherence to siloed nonfiction genres. Recent bestselling cross-genre fiction with overt environmental themes present a path forward for Antarctic nonfiction to reach popular readerships. This will entail a fusion of traditional tropes of “heroic” Antarctic nonfiction with conventional themes found in polemic environmental literature. The creative writing aphorism “show don’t tell” is particularly salient in this necessary method of Antarctic storytelling.

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A collaborative process between Antarctic researchers and Communication scientists for scientific videos production in order to popularize the polar sciences: seeking an accessible language to the general public

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In Brazil, the Antarctic sciences are absent from the school curriculum and rarely have space in the media. Besides, or because of that, there are no enough media materials with accessible language to the general public. This fact leads to a lack of scientific knowledge about Antarctica and its role on the planet.
In this research, we studied the guidelines for the production of scientific videos for the popularization of the Antarctic sciences. Eleven scientists participated in the production team, collaborating with the creation of scripts, providing images, and searching for an accessible language to the general public to expose their research.
The conception of the videos considered the three dimensions of scientific literacy proposed by Miller (2000): the mastery of a basic vocabulary of scientific concepts, the understanding of the nature of the scientific method, and the understanding of the impact of science and technology on individuals and society. For this, the videos expose the processes of Antarctic research: hypothesis survey, logistics for field research, methods of data collection and analysis, systematization and interpretation of results, and their impacts.
The partnership with scientists to search for a language accessible to the general public allowed to transmit a trustworthy image of science, facilitating the understanding of scientific concepts, processes, and principles. The process also supported to improve the communication skills of scientists and the learning of Antarctic subjects by the production team. It is still a challenge not overcome, the quality of the images produced in the field.

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Antarctic Expedition - contribution of a digital serious game, accessible to the blind and deaf, to the Antarctic sciences popularization

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Digital serious games, like educational ones, aim to bring changes in the real world. The game strength as a media to science popularizing lies in its rules and procedures. By learning the game rules, the player learns how to proceed in the world outside of it. Fun also plays an essential role in scientific literacy, as it promotes the dialogue of knowledge with practical actions, in a ludic way.

Based on these premises, we developed an educational RPG (Role Play Game) for interdisciplinary science teaching. In the Antarctic Expedition game, accessible to the blind and deaf, the player assumes the role of a tourist who, when visiting the continent, collaborates with some scientific research. The game has four missions: citizen science of bird and whale identification, and Brazilian research in vegetation and paleontology.

The game rules simulate real research processes. For example, in the paleontology mission, the player must follow all the steps to collect and identify fossils. Handling samples properly is one of the rules, when destroying a sample, the player loses the game and must restart it.

The player's interaction with the game is the most significant element of learning. He learns by talking to naturalists, playing mini-games, and engaging in research.

The simulation of scientific processes supports the transposition of the game symbolic world - the rules - to the real world - the research procedures -, demonstrating that the game is a fun and valuable medium for Science Education and the science popularization.

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POLARCASTERS - strategies for scientific literacy through video production by non-scientific public

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Studies on scientific literacy highlight the failure of communication models based on the cognitive deficit and show the tendency of dialogical communication models, which foster democratic public participation. Abandoning the deficit model does not mean ignoring its existence. Research continues to indicate the difficulty of understanding, by the general public, about science and its processes. There are still discussions about who should communicate science: scientists who master the content or communicators who master communication techniques?
In this work, we assume the dialogical communication model to develop scientific literacy strategies about Antarctica. We implemented, in two undergraduate classrooms, one in elementary education and two teacher training programs, a learning methodology mediated by the scientific video production: the PolarCasters project. Aimed at teachers and students, it offers video production workshops and guided studies on Antarctica over three months.
The more than 200 participants produced videos about research conducted in Antarctica, experimenting with different methods, genres, and languages. Forty-two videos were published on a YouTube channel called PolarCasters Antártica.

As a result, the Antarctic sciences are no longer the exclusive domain of scientists. The methodology fostered the construction of knowledge, and by assuming the role of science communicators, participants have become protagonists in the processes of producing scientific videos, demystifying science, and inserting Antarctica in the school curriculum. In future studies, we intend to analyze the impact of scientific communication being produced by the non-specialist public, and not by scientists or communication professionals.

1345

The Science Hero's Journey--Using Storytelling in Science Outreach

Marlo Garnsworthy[1]
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Individual researchers are increasingly called upon to participate in science outreach. But polar scientists soon run into what I call the "Polar SciComm Problem": It is relatively easy to draw people in with remote adventures, extreme beauty, and penguins, but keeping the audience's attention while conveying sophisticated science concepts is a challenge. What happens at the poles seems remote or removed from "real life". The public has little concept of the scale of Antarctica and its glaciers, and Antarctic science in a warming world can raise anxiety, causing people to quickly tune out.

Storytelling can not only capture an audience's attention but keep it while you explore the science and why it matters. Using my experience as an editor, writing teaching, author/illustrator, and Outreach Officer, I discuss the usefulness of textual and visual storytelling in polar science communication and outreach.

I explore how traditional narrative structure--with a beginning, middle, rising tension, climax, and resolution--can be applied to outreach for various audiences, from young children through the adult layperson. Using specific examples of my own polar science communication work, I examine how scientists can harness traditional narrative structure in lab and expedition blogs, expository social media posts, educational products, and public presentations. Let me take you on a narrative journey into polar outreach.

1304

Going South, Aiming North—Perspectives on Successful & Creative Antarctic Outreach

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Accelerating ice loss from the West Antarctic Ice Sheet, not enough political action to combat climate change, and successful disinformation campaigns make it clear that vigorous, targeted, and coordinated science communication must be among the top priorities of the Antarctic community. But with a range of media ever competing for the public's attention, capturing the layperson with engaging, simple, and scientifically accurate information is challenging. Not only institutions carry an obligation to spread accurate information; individual polar researchers, together with dedicated communicators and creatives, are on the vanguard in this battle to capture public awareness, educate, and inspire action.

I discuss what the Antarctic community can learn from a highly successful outreach program. The Onboard Outreach Program (OOP) aboard the JOIDES Resolution sets the gold standard for science communication, outreach, and interaction with a broad, global audience and is an excellent instructional model. I examine the success of the OOP's multifaceted approach to public engagement and education, plus resources I would add to such programs for the Antarctic community.

My idea outreach program includes: an accessible, visually appealing, and easy to navigate centralized information source�and I explore its various components; coordinated social media platforms; downloadable educational resources aimed at preschool through the adult layperson; live interactive broadcasts between scientist and audience; and opportunities for growth of scientist as communicator. It encourages an individual to use their unique communication skill set and eases the burden on individual scientists by providing readily sharable information and a strong network.

1322

All Hands on TweetDeck!--A Social Media Crash Course for Scientists

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You suspect you need to do it, but concerns about social media leave you cold. You have a languishing Twitter account, but you don't understand how to use it. You're an avid lurker, but you have no idea what to tweet. You're already using social media, but your posts just aren't hitting the mark. Whatever your social media experience, this is the crash course for you.

As a freelancer, I have used my social media platform to build a successful business and a strong presence in my field. As the veteran Outreach Officer of two Antarctic research cruises, I am well-versed in how to apply social media tools to polar outreach, the limits of using social media in the field, and in using simple, engaging short-form posts to convey complex science to a broad audience.

I discuss the utility of the three top social media platforms and convince you why should use Twitter (and Instagram)--for both public outreach and building your career. I show you how to get started, plus what to consider as you develop your social media presence.

We'll explore how to acquire a following, what to tweet and what to avoid, how to use hashtags and threads, how to avoid falling down a time-sucking rabbit hole, troll avoidance, and other ins and outs of Twitter and other social media. I highlight the importance of amplifying the efforts of organizations, individual scientists, and creatives on social media. It's all hands on deck--the polar community needs you!

1360

Media reporting on sea level rise in Aotearoa New Zealand (1988 – 2018)

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New Zealand scientists have been communicating about sea level rise to publics, via the media, for the past three decades. We identified a corpus of 541 news articles about sea level rise from four New Zealand print publications (newspapers and magazines) from 1980 to 2018.
Analysis of the articles shows that while headlines are often sensationalist, presenting extreme sea level rise scenarios, the content of the articles is more measured and is usually in line with IPCC projections. Here, thematic analysis of the articles identifies the ways the media has (i) quantified the amount, timing and rate of sea level rise projections, (ii) identified quote-worthy sea level rise experts, (iii) made connections to Antarctic ice melt and (iv) presented the ways in which scientists, publics, businesses and government are responding to the threat of sea level rise.
Results of this research into media perceptions of sea level rise, which is funded by the NZ SeaRise programme, will have value for scientists communicating about Antarctic ice melt, sea level rise, and climate change more broadly, in the years ahead. As part of this paper, we will present some initiatives by the NZ SeaRise programme to enhance media coverage of sea level rise in Aotearoa New Zealand.

786

Reporting Antarctica: How the News Media Frames Antarctic Science in a Changing Climate

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For the majority, Antarctica is a mysterious frozen continent: a place of science and international collaboration; and a symbol of fears about global warming. But from where do these ideas generate and who decides the terms of reference for the publics' understanding of Antarctic science? The role of news media has been largely overlooked in scholarship, which seeks to understand public engagement with, and understanding of, the Antarctic region. This is a significant gap in research, given that the news media is the public's main source of information about science. As images of calving icebergs and collapsing ice shelves become more commonplace on news feeds, news media's role in framing key issues such as climate change deserves exploration. Using the Australian news media as a case study, data collected from Australian online news media outlets over a recent 12-month period will be analysed to identify prominent frames and voices in news discourse related to Antarctic science. The data will be considered in light of existing scholarship which examines the role of journalists as gatekeepers of science stories and the politicisation of science. This presentation argues that exploring journalistic representations of Antarctica science has the potential to challenge assumptions about the role of news media and scientists in communicating issues such as climate change.

560

‘Planetary conscience’: a useful concept in Antarctic artistic enquiry?

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This paper introduces the concept of ‘planetary conscience’ as a lens to consider two Antarctic arts-based enquiries. I define ‘planetary conscience’ as having a heightened awareness of the interrelationships and interdependences that create the conditions for, and sustain, life on Earth, coupled with conscious acts that seek to minimise human environmental impact.

Leave Only Footprints critically considers the tensions and contradictions between human presence and environmental impact in Antarctica. Created over seven seasons of working in the Antarctic Peninsula region, the project has evolved to embed environmental conservation work within the artistic process. Antarctic Sun Lines uses solargraphy to record the dynamic relationships between Antarctica, the sun and the tilted orbit of the Earth. Since 2015 the project has developed into an international collaboration with over 50 Antarctic organisations involved. Audience responses during a public exhibition at Christchurch Art Gallery / Te Puna o Waiwhetū in 2019 suggest that the work stimulates curiosity in planetary dynamics. Both enquiries can be understood as reflecting ‘planetary conscience’ in their conceptual foundations, and in the questions prompted during the creative process and exhibition of the work. Further, the work has resulted in conscious environmental action as an integral element of the art-making process.

In the Antarctic context, we know that ‘the ice’ is fundamental to the creation and continuance of the ocean and climatic systems essential to life, therefore the concept of planetary conscience may be useful in our cultural, environmental and political engagements with the continent and the wider world.

1054

Citizen Science & Plastic Pollution Engagement in Antarctica

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Plastic pollution has captured the attention of the world and presents an opportunity as a “gateway topic” to engage the public with environmental issues. Making the connection between the behaviours we have at home with the isolated Frozen Continent can often be challenging for educators and scientists in the polar field. Here we present the Antarctic Sabbatical, a project funded by Airbnb, in partnership with the Ocean Conservancy and Antarctic Logistics and Expeditions, which afforded five members of the public with an opportunity to engage in polar research and microplastics investigations in Antarctica. The “Antarctic Sabbatical” project encompassed training and a lecture series delivered in Punta Arenas, engagement with local partners (including the Instituto Antartico Chileno and Gaia Antarctica Research Centre, Universidad de Magallanes), fieldwork on a glacier, and development of Environmental ambassador skills. Carrying out a pilot-scale study of microplastic investigations out of Union Glacier Camp, we illustrate the plausibility for regular data collection utilising already existing tourism for “Extreme Citizen Science” and plastic pollution engagement in Antarctica.

576

When there was no ice - an exhibition that brings audiences closer to the research carried out in Antarctica

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"When there was no ice - new discoveries from the Antarctic continent" was the first exhibition organized by the Museu Nacional/UFRJ after the fire of September 2nd, 2018, that seriously affected the palace where the main part of the institution was housed. The main purpose of the exhibit was to show the climatic changes that occurred in Antarctica throughout deep time and how research concerning paleontology and geology is done in this region, using the results obtained by the PALEOANTAR project, that has collected fossils mainly in the Antarctic Peninsula. The exhibit is divided into two main areas. The first shows the current conditions of Antarctica, including elements of the present flora and fauna - what can be regarded as common knowledge. But in the second part, the visitor is invited to travel some 70 million years ago when the Antarctic Peninsula, was covered by gymnosperm forests and inhabited by different creatures in land and sea. New results from the PALEOANTAR expeditions are shown, including flying and marine reptiles. Concepts of climatic change, plate tectonics and "how do we know what we know" are presented. There are also areas where the public can have a glimpse on the daily life of a researcher working in the frozen continent. This kind of activity brings the public closer to Antarctic research.

913

If you have lemons make a lemonade: challenge and inspiration for polar and climate change education.

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The tropical climate conditions typical of much of Brazil tend to limit Brazilian perceptions of the frozen polar regions. This is especially so in regions with limited scientific knowledge and no involvement in polar research. The activity “Why should we study the poles of the Earth?” was organised by APECS-Brazil for students from the fourth and fifth elementary school grades at the Escola Estadual 13 de Maio, in the city of Porto Esperidião, Mato Grosso State, near the Brazil-Bolivia border. Topics addressed included polar biodiversity, the proximity of Brazil to Antarctica, the main impacts observed near the poles resulting from climate change, and our responsibility to protect these regions. Symbolising the commitment to reduce human impacts on the Earth's climate, 30 native and fruit trees were planted by the students involved. Unfortunately, these trees will not bear fruit or create future shade, as a machine cut them a month after the planting, undoing all the effort of the students. However, teachers, students and APECS-Brazil used this experience to exchange letters reporting their feelings, challenges and renewed commitments in the face of such events. Twenty-one letters were written by the students and posted to APECS, expressing the most beautiful and hopeful thoughts for a better world, which showed that the teachers and students were very involved with the activity. Challenges will always remain, but in response there is also a new way of creating, inspiring, learning.

1021

The urgency of finding new ways of communicating science while Antarctic ice is melting

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The warm temperatures of February 2020 renewed a global concern in the media about the future of the White Continent. Such temperatures raise new questions about our role as researchers. Scientists communicate the results to their peers through papers, but the impacts of climate change in Antarctica also requires creative and effective ways of communication. Among different outreach activities related to Antarctica in Ushuaia, the "Café Antártico" ("Antarctic Coffee") is an initiative performed by researchers in this Antarctic Gateway City. Three key ideas inspired the criteria for its organization since 2014: (i) interdisciplinary objectives in the invitation of speakers; (ii) itinerant venues in town; and (iii) general and interinstitutional public is invited. In doing so, we expect to shorten the distance between the people interested in Antarctica and those with Antarctic experience. Thus, we offer a meeting point beyond their public or private occupation to discover or deepen their knowledge about Antarctica. Although the "Café Antártico" is not an isolated action in science communication in Ushuaia, our efforts are not enough: climate change represents a new worldwide challenge to the public engagement of science communication. This presentation aims to discuss experiences of public engagement in Antarctic science and to articulate with other initiatives.

1337

The Fantastic Feedback Loop - how Happywhale attracts and holds public interest in science, Antarctica and its whales.

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[1]International Association Of Antarctica Tour Operators (IAATO), South Kingstown, United States, [2]Happywhale, Los Gatos, USA

The International Association of Antarctica Tour Operators (IAATO) states that ambassadors are created through responsible tourism, creating awareness and advocacy that lead to positive conservation outcomes. We propose that this ambassador effect can be significantly deepened when visitors actively contribute to Antarctic research through citizen science, particularly when it includes a rewarding feedback loop. We created a web-based citizen science platform (Happywhale.com) to collect images and sighting data for marine mammals, and implemented automated image recognition for humpback whale fluke photo ID. Automated feedback mechanisms notify contributors of research results, informing them about the identity of whales they have photographed when identified, and also alert them whenever 'their' whale is seen again.

Happywhale has seen organic growth since inception in 2015. It has received 267,871 images globally from 6140 public contributors and research collaborators, with 859 contributors sharing images from the Antarctic. Happywhale is an attractive, easy platform to use, with 35% of IAATO operators running the project on their vessels in the 2018-2019 season. The key to its growing success is rapid feedback to contributors which educates about whale encounters, with links to known sighting history. It encourages greater attention to marine mammal sightings, potentially inspiring greater efforts to engage with science. The resulting dataset has identified approximately 25% of individual humpbacks on the Antarctic Peninsula, a valuable asset for population modelling, and informed IAATO development of an extensive vessel slow down zone.

399

“A community-shaped hole” –public engagement, policy, and Australia’s Antarctic gateway.

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When it comes to public engagement, the Antarctic sector is faced with the singular challenge of attempting to connect with a populace who will likely never experience the continent first-hand. In this environment, the Antarctic gateway cities of Hobart, Christchurch, Punta Arenas, Ushuaia and Cape Town are attracting increasing academic attention (Bertram et al., 2007, Elzinga, 2013, Boekstein, 2014, Hall, 2015, Roldan, 2015, Leane, 2016), and offer a unique opportunity to foster indirect engagement strategies that build on the cities’ well-established geographic, cultural, economic and scientific Antarctic ties. At an Australian level, we are seeing increasing political investment in Hobart’s gateway status through developments like the forthcoming Macquarie Point Antarctic & Science Precinct (Australian Government, 2019). Little is currently known however, about the perspective held by Hobart residents themselves, and the local community’s contribution to the Antarctic sector remains largely unexplored.

This paper will examine the ways in which Hobart residents are characterised in public policy. Drawing upon the emergent results of PhD research concerning civic participation in the gateway cities, this paper will present the results of a mixed-method policy analysis using rapid policy network analysis (Bainbridge, 2014) and various close reading techniques.

The analysis will argue that Hobart residents are not currently seen as stakeholders in Australian Antarctic policy, and that there is a corresponding under-representation of the social and cultural spheres of activity within Hobart’s Antarctic life, something that has implications for our ability to strategically engage gateway residents in Antarctic issues of local and global importance.

108

Launching 'Polar Alien Hunters' – a new educational biosecurity campaign to protect Antarctic biodiversity

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Polar Alien Hunters is an educational biosecurity campaign that uses comics to highlight the issue of alien species in Antarctica, the researchers who study them, and what we can do to protect our vast icy wilderness. SCAR-COMNAP 2020 will mark the official launch of the initiative, where will share our first 3 comics introducing the issue of alien species in Antarctica and invite researchers, logisticians, managers and national operators to join us and become Polar Alien Hunters. We will also present our own research on non-native species in the Antarctic region to contextualise both the problem of non-native species and the need for a coordinated international campaign.

The main goal of the project is to share educational material with visitors before they leave for Antarctica, ensuring that they do not accidentally take any 'aliens' with them on their trip. Our engaging and fun comics will instruct and educate tourists, researchers, and support staff alike on the risks of introducing an alien species, their personal responsibility for carrying out biosecurity measures, and why coordinated effort is needed across nations and sectors. The topic of non-native species introductions is a priority for the Committee for Environmental Protection and Polar Alien Hunters represents the first effort to conduct an Antarctic biosecurity campaign across all nations and sectors that visit the Antarctic region.

771

Infographics to support communicating science to the public and policy makers: summarising the science of the first Marine Ecosystem Assessment for the Southern Ocean

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Effective science communication regarding global change has taken on new urgency as a result of dramatic increases in the quantity of information – derived from 'big data' and technology – directed towards knowledge users (policy makers, government and the general public). Moreover, the volume of information is such that it is difficult for anybody to be across all the detail in a time-poor world. Therefore, efficient means of delivering key messages is important. Methods that leverage people's most dominant faculty for receiving information – visual processing – through graphic visual representations of information, data and knowledge (termed 'infographics') are increasingly being implemented to communicate research in an immediately intuitive and engaging manner.

The first Marine Ecosystem Assessment for the Southern Ocean (MEASO) aims to provide a current assessment of the status and trends of marine habitats, species and food webs around Antarctica. The assessment created a valuable learning opportunity for collaboration between researchers and graphic artists to distill and convey key scientific concepts and results of interest to the public and policy makers in a visual narrative. Here we discuss the process of co-creation of a series of infographics produced from MEASO, the lessons learned from this process and, in our experience, how the use of graphics may enhance education practices to effect change.

1047

India's scientific endeavours in the polar research: Bridging the gap between science and society

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Scientists are concerned about the implications of human-induced changes on polar regions and their butterfly effect across the globe. Though, the same must be communicated in the simplest form among the general public and policy-makers. National Centre for Polar and Ocean Research (NCPOR) is a nodal agency for Indian Polar Programs (Antarctica, Arctic, Southern Ocean). NCPOR has undertaken a number of outreach activities in recent years to raise public awareness about climate change and to highlight Indian endeavours in Polar Regions. Polar outreach activities aim to connect teachers, students and citizens across India through the cultivation of interest in the polar research among enthusiastic scientists, educators and communicators. To achieve this, different methods such as organising outreach program/workshops, participation in exhibitions, public lectures, etc have been implemented. To promote audience participation, quiz contests, scientist-student interactions, panel discussions, screening of science films, etc. have organised. Over the past year, NCPOR interacted with more than 8000 students and general public using different platforms: educational visits (28%), participation in the scientific exhibitions (64%) and outreach events (8%). NCPOR's initiative biennial 'National Conference on Polar Sciences' provided a platform for Indian polar community to address challenges, share research findings and enhance collaborations. NCPOR also liaise with APECS to conduct outreach activities. Integrating the latest technology like virtual reality, augmented reality are some of the tools planned for future outreach activities to deliver an immersive experience of Antarctica. India will host 10th SCAR conference in 2022 to encourage international scientific collaborations with SCAR members.

1535

How do we build capacity, resilience and community connectivity to the polar regions (and each other) from afar?
Transdisciplinary Antarctic climate communication landscapes and the many functions of art.

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Art, its processes, methodologies, aesthetics and interdisciplinarity, connect audiences to knowledge and place that is complex and outside of regular experience. Here we examine how art can be used to improve communication of climate science. The central question is “can collaborative, inclusive and inter-generational project design with stakeholders, scientists and artists, create more science-positive futures and problem solvers?” We address this question with a project developed to communicate climate science using story-telling and art-making in an educational context with an embedded social science framework. The output generates community collaboration and, in doing so, strengthens the impact of the shared science knowledge. This then extends through to policy with increased care, concern and action at a societal level. The work also shifts definitions of the term “stakeholder,” whereby the art allows audiences to reconsider stakeholders and publics that exist within an ecosystem rather than a hierarchy, while improving trust between science and the public. The project developed a data-driven evidence base to quantify the strength of the outcomes. The work suggests a combination of Antarctic science research stories, place-based methodologies and art can affect change within our communities.

1708

Engaging schools with a new map of Antarctica

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To commemorate the 60th anniversary of the Antarctic Treaty, the NZ Antarctic Society in partnership with Land Information New Zealand produced and printed a new map of Antarctica, which was sent to every school in New Zealand at the beginning of the academic year in 2020.

Themes of the map addressed climate change issues, including ice sheets, ocean currents and sea ice. Seabed bathymetry of the Southern Ocean was also shown, including the continental shelf. The map highlighted the critical interconnection between continent and ocean, and how they impact the global climate system. The map was supported with the accompanying 'Antarctic' magazine of the NZAS

The new map, which was a radical redesign of traditional cartographic conventions, was positively received by schools, with many seeking to deepen their engagement with the NZ Antarctic Society. As a result of the map initiative, there is now an ongoing program of educational outreach by the NZAS to schools throughout the country.

647

Communicating information about Antarctic Science and Research to first year students at Stellenbosch University.

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The Antarctic Legacy of South Africa (ALSA) focuses on communicating science at different levels. One level is at tertiary institutions to enlighten students on research done in the Antarctic by South Africa. An opportunity presented itself when the Faculty of Science at Stellenbosch University added a new compulsory module, ‘Science in Context’ to be completed by all first year BSc students. The purpose of this module is to expose students to the benefits of integrating knowledge from different disciplines when approaching scientific topics. ALSA became involved in this module in 2018 by supplying topics, giving lectures, creating podcasts, as well as end-of-year evaluation of the students’ projects. Antarctic-related topics(12) were compiled in conjunction with ALSA and making it one of the key role-players in this module. Students made use of the ALSA online archive as well as the links to the different research projects within SANAP. Students presented their work, which gave the rest of the students the chance to learn more about these Antarctic-related topics. One of the topics that was chosen multiple times in 2018 was; ‘Invasive species can have devastating effects on their environment. Consider the mice invasion on Marion Island. How did it happen, why is it problematic and what can be done about it?, and in 2019 “Scientists and researchers spend 2 to 14 months in isolated and extreme weather conditions with limited contact with family and friends. How does one prepare for such an expedition?” (The presentation will include excerpts of the projects.

995

The Effect of Exposure to Antarctic Focused Art and Science in Shaping Attitudes Towards Climate Change.

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Climate change is an exigent problem that requires a substantial increase in action to mitigate. It has been suggested that exposure to climate change inspired music may shape climate change attitudes by evoking emotions and influencing system 1 (affective, automatic and fast) judgements. A recent study investigated whether different combinations of auditory stimuli relating to the Antarctic region influenced participant attitudes towards climate change. 134 online participants were exposed to one of four stimuli conditions: Antarctic inspired music, science information with Antarctic inspired music, science information with 'neutral' music (i.e. not emotive or inspired by Antarctica), or science information only. Participants completed pre- and post-stimuli exposure measures of implicit and explicit Biospheric attitudes (a measure of climate change attitudes) and positive and negative affect. Results indicated that irrespective of the stimuli, both implicit and explicit Biospheric attitudes were significantly higher post-stimuli exposure, and positive affect lower. Furthermore, participants exposed to science information only had the highest increase in Biospheric attitudes, Antarctic inspired music only the lowest, and all music conditions showed a significant decrease in positive affect. These results imply that combinations of Antarctic inspired music and science information can shape Biospheric attitudes, and whilst positive affect may decrease it does not directly relate to attitude change levels. These findings have implications for communicators seeking to engage the public with the issue of climate change.

1433

Action Group on Public Engagement with Antarctic Science

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A primary goal of SCAR is to “communicate scientific information about the Antarctic region to the public.” To this end, SCAR, national SCAR members, research organisations, and individual scientists conduct significant science communication, public engagement and outreach activities. At the same time, the field of study variously known as “Public Understanding of Science,” “Public Awareness of Science”, and (more recently) “Public Engagement with Science” has developed rapidly, and now has its own critical literature, theoretical debates, and scholarly forums.

In 2019, the SCAR Standing Committee on the Humanities and Social Sciences endorsed the formation of an Action Group on Public Engagement with Antarctic Science, proposed by Elizabeth Leane and Rebecca Priestley.

The aim of this Action Group is to foster the academic study of public engagement with Antarctic science. The group’s members will describe, evaluate, contextualize and critique the diverse ways in which scientists, communicators, artists and educators engage with different publics, and the ways in which publics engage with Antarctic science. Members of the group will apply the methods and findings emerging from the scholarly fields of science communication and public engagement with science to produce analyses and recommendations for Antarctic researchers.

In this session we will discuss the aims of the Action Group, identify existing initiatives aligned with the aims of the Action Group, invite researchers and practitioners to join the group, and make plans for future activities.

1520

Public perceptions of sea level rise in Aotearoa New Zealand

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The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (2019) stated likely sea level rise projections to 2100, under different scenarios, of 0.29m to 1.1m (relative to 1986-2005). Some scholars, though, have published, or spoken publicly about, the possibility or likelihood of higher sea level rise by 2100. In Aotearoa New Zealand, while most reporting aligns with IPCC advice, media also give coverage to extreme and catastrophic scenarios. To investigate public perceptions of sea level rise, we conducted a representative survey of 1100 New Zealanders comprising 15 multi-choice questions.

Respondents were surveyed on understanding of the mechanisms of sea level rise, and the amount, rate, and timing of sea level rise expected this century and beyond. Despite New Zealand media coverage not perpetuating this misunderstanding, respondents had a strong belief that the main contributor to sea level rise is melting sea ice, with it selected as the single main contributor by 32% of respondents and one of the top three (along with 'other' and 'melting ice sheets') by 66.5% of respondents. While more than half of respondents believed sea level rise by 2100 would be up to 1m, the remaining respondents overestimated sea level rise, choosing 'up to 2m' (14.9%), 'up to 5m' (10.7%) or 'more than 5m' (8.2%).

Results of this research, which is funded by the NZSeaRise programme, will have value for scientists communicating about Antarctic ice melt, sea level rise, and climate change more broadly, in the years ahead.

1566

Involve Latin America and the Caribbean countries for Antarctica in a changing climate

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Today we live in a changing world, where not only climate change is putting pressure on the different earth systems. Changes in geopolitics, business, and markets are putting more pressure on different ecosystems. Antarctica is well known as a thermal regulator for the earth's climate, although scientists have this information, it has not been enough to take concrete actions and stop those activities which put at risk. Antarctica should be a priority for science diplomacy and science-policy interface worldwide, that is why RedLAtM, an atmospheric science organization, has started an initiative for young scientists in the global south specifically in Latin America and the Caribbean, in effort to connect the Antarctic region with society, a project called action for Antarctica was developed to involve the younger generations through communication, outreach and education to bring Antarctic scientific research to the general public and also empowers and develops capabilities especially atmospheric and climate scientists, to bring their knowledge to the highest level and their local governments to help these countries adhere to the Antarctic treaty because to the global change needs south overview must be also incorporated. The global south must be positioned for Antarctica decision making in order to combat the scientific gap that still exists between north and south.
Finally, we facilitate the vision that scientists have the power to communicate to society the value of polar areas and especially Antarctica and the importance it has for life and climate literacy to achieve the Sustainable Development Goal 13-Climate Action.

1567

"Inviting Antarctica to your home": an evaluation of public engagement with Antarctic science, policy and technology.

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Calls for greater public engagement with Antarctica and its pressing environmental issues have been at the forefront of the international science community in recent decades. Effective communication of Antarctic issues can create public awareness of the challenges facing the southern Polar Region, which has the potential to motivate change in human attitudes towards the protection of the environment. These initiatives require dedication, time and funding to create (and deliver) Antarctic education and outreach programmes accessible to the public. Yet, there is little understanding to what degree the public engages with Antarctic matters through these initiatives, and how effective science communication is measured in the Antarctic context.

This paper focuses on the drivers and barriers to the education and public engagement with Antarctic science, policy and technology found in Punta Arenas (Chile). Data for this research were collected through participant observation, an online survey and by conducting in-depth interviews with local science communication and education stakeholders. This presentation shares the preliminary results of this research and proposes a set of qualitative indicators to assess effectiveness in public interest and community engagement with Antarctica. This research took place in 2019 under the COMNAP Fellowship scheme.

514

From ‘gateways’ to custodian cities? Rethinking the Antarctic Gateways

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The Southern Hemisphere cities of Cape Town, Christchurch, Hobart, Punta Arenas and Ushuaia are recognised as the main Antarctic gateway cities in the polar community with a recognised Antarctic urban and cultural heritage. These cities today have significant transport infrastructure and scientific logistics to and from Antarctica, and an increasing public engagement with the South Polar Region. Taking advantage of their cultural, ecological, economic and political ties with Antarctica, these cities starting to rethink ways to be more than primary exit/entry points for polar science programs, tourism or fishing. This paper discusses the key final results of the international collaborative cultural research project Antarctic Cities and the Global Commons: Rethinking the Gateways. The paper outlines a particular mode of engaged research, showcasing a series of social research tools, creative methods and critical perspectives, that could reorient the role that these cities have within their national and global contexts, and inspire youth and decision-makers alike to create a novel ways of public engagement and fostering a sense of Antarctic custodianship across the five cities.

1445

Embedding an 'Engagement Incubator' into Antarctic Research

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It has been posited that the International Polar Year 2007 – 2008 catalysed a step change in the value and visibility given to science engagement in polar research. However, while this may have led to more researchers 'doing Antarctic outreach' and more engagement professionals being contracted to 'deliver Antarctic outreach', there still appears to be a lack of strategic engagement, or awareness of public engagement theory, embedded into these research efforts. This is for many reasons including limited time, funding and expertise.

This paper reports on a new approach to embedding engagement within research efforts. In February 2020, fifteen people representing nine separate research projects gathered together for the inaugural two-day 'Te Pūnaha Matatini Engagement Incubator'. The goal was to interrogate, develop and embed engagement strategies for a diverse set of research initiatives ranging across conservation, microbiology, mathematics, ecology, information management, urban planning and Antarctic policy. Participants all worked in Aotearoa New Zealand and included researchers across a range of career stages, from doctoral student to professor level. The outcomes of the Engagement Incubator were greater articulation of the goals of engagement for each project, a deeper understanding of the implicit and explicit expectations by various key actors, and a clearer vision for resources required, delivery and evaluation.

This paper will provide an overview of the context, goals and delivery of this first Engagement Incubator and explore the potential for its application across a range of Antarctic research and policy initiatives.

1694

Top-down and bottom-up approaches between middle school students and Antarctic Museums in project base learning and science outreach: how to engage young generations into real Antarctic research and transform Museums into powerful learning opportunities

Stefano Schiaparelli[1,2], Paola Gatti, Eleonora Gatti, Bianca Maresca, Lucia Guideri, Viola Rossi, Tommaso Marinelli, Barbara Andreoni[3], Paola Pippo[3], Federica Brigandì[3]
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We live in an historical moment characterized by notable climatic changes and an ever-growing attention to the environment. The best way to commit people to understand major problems of our planet is to give them direct access to information and knowledge. There are several powerful ways to engage students in these activities, but this is typically a “top-down” process, where selected, pre-packaged information is drained from the “ivory tower” of research to the public. Less common instead is the “bottom-up” approach, where motivated students ask to be active part of this communicative process. Here we present a study case where a group of 10 to 15 years old students (here also participating as authors of the abstract), working together outside class activities, have developed a new idea of collaboration with public Museums. With the coordination of their teachers, they asked to the Italian National Antarctic Museum (MNA, Section of Genoa) to become their mentor in order to: 1) understand Antarctic research, and 2) disseminate scientifically correct information to young generations based on ideas and communication tools designed by themselves for other students of the same age. This was a successful experience for both sides and this inedited outreach mechanism could be exported to any other Museum, even outside Antarctic topics, and proposed to other schools as a general model for active learning.

1396

Awakening to Science through Dive into Science USP, a program of women scientists dedicated to young girls

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The dissemination of Science outside universities, showing society the role of women scientists and the importance of Science for the country`s development, the encouragement of gender equality and the empowerment of women in scientific areas are needs raised by society and by national and international organizations aiming at world development. In this context, the Outreach and Education Program Dive into Science USP aims to encourage the inclusion of girls in Science, especially in STEM, introduce scientific literacy, humanize the figure of a scientist, sow the knowledge acquired by the participants for the school and family environment. For this, a free course, organized by a strong team of women at different levels of education, is offered at the Oceanographic Institute of the University of São Paulo for 50 girls between the 5th and 9th grade of elementary education, from public and private schools. A wide variety of scientific topics are offered, including Oceanography and Astrobiology with examples of the Antarctic research, taught by women scientists through theoretical and practical classes at laboratories and visits to museums. This course and other related activities played a very positive impact on participants, were widely publicized in the media, and received recognition from the United Nations (HeforShe Impact report). We hope that the project will have a long life and reach other audiences in the near future. Finally, we believe in the crucial and transforming role of basic education combined with science for the formation of a citizen in a more inclusive world.

952

Social Media as a Tool for Polar Science Outreach: Influencing the Public and Policy Makers

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The evolution of various social media platforms has made it relatively easy, simple, and economical to share scientific results and thoughts. With growing recognition among the general public and decision-makers about the looming climate and environmental crisis, the role of social media has become more pertinent than ever in communicating climate change knowledge. During my participation in the International Ocean Discovery Program (IODP) Expedition 382, the Onboard Outreach Officers shared on-going experiments and science to the public. IODP Expedition 382 publicised numerous onboard lab activities and the expedition objectives through blogging, Vlogging, and other social platforms (such as Twitter, Instagram and Facebook). A large number of students from elementary school through university level from different nations were engaged by scientific activities during the expedition. Many researchers wrote blogs during Expedition 382 on the JOIDES Resolution website and received significant attention from the public. We simplified the complex information so that it can be understood by elementary school students and laypersons. The science team learned about outreach activities and the efficient and responsible use of social media during the IODP Expedition 382. Based on my experience of science communication, here we discuss a new model of outreach education which involves debates, creative videos, online book reviews, and organizing town halls which are more engaging to the general public as well as relevant for policymakers.

1501

Whakairo (traditional carving) as research

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How can scientists undertake research, and partner with the community, in ways that make sense to both? Here we describe research undertaken between scientists and Indigenous Māori partners in New Zealand, that embraces Indigenous frameworks and ways of knowing in relation to the future of Antarctica. Whakairo is a traditional Maori carved art form that embodies values and history, and acts as a repository of knowledge. In a five year funded research project on the Ross Sea Marine Protected Area, we are partnering with tribal groups to begin articulating Maori aspirations and concerns for Antarctica. We chose to begin with a research project expressed through a culturally important medium, whakairo, with expert carvers from both Ngāi Tahu and Ngāti Wai. In 2018 we came together over a year to wānanga, or discuss and work through this project. In 2019, James York and Poutama Hetaraka travelled to Antarctica (together with film maker Vanessa Wells) to finally complete the carving of a door lintel and sides, which was unveiled at Scott Base. The whakairo draws on centuries old concepts of kaitiakitanga to speak directly to Māori values and connections to the Ross Sea. It also draws attention to the partnership of mātauranga Maori and science, the maramataka (traditional phenological calendars) and global climate change and demonstrates how Māori and scientists can find shared values, insights, and impetus to work together. We discuss the value of research in its different forms, and how communities engage with science and research in different ways.

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Communicating Antarctic issues of global importance: lessons learned from scientists, educators and policy makers

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Antarctica is now recognized to influence the rest of the planet (Rintoul et al. 2018), with Antarctic scientists working in hot topics such as climate change and ocean pollution. From an Antarctic Treaty perspective, there is a clear view that countries are becoming more conscious of the growing interest in Antarctica and the value of education. We show that the number of papers mentioning “education and outreach” submitted to the Antarctic Treaty Consultative Meetings (ATCM´s) were low up to the 1990´s. Since then, particularly in the last 5 years, the number of papers submitted at ATCM´s increasing considerably (Xavier et al. 2019). As an example of a country engaged in SCAR and ATCM´s, we review the activities and lessons learnt while working with Antarctic scientists, educators and policy makers in Portugal with other countries, in their efforts to communicate “Antarctic science” on urgent global issues, in collaboration with Polar Educators International (PEI), the Association of Polar Early Career Scientists (APECS), SCAR Capacity Building, Education and Training advisory group and the ATCM Intersessional Contact Group on Education and Outreach. We provide evidence that activities engaging scientists and educators, while informing policy makers, contribute to define a common and effectively strategy to communicate polar knowledge and advance awareness to a range of different audiences (Xavier et al. 2018, Roop et al. 2019, Xavier et al. 2019)

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ANTARCTIC FUTURES

Juan Francisco Salazar, Bob Frame
Victoria Nuviala

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

1664

Antarctic Futures: Is it worth looking for what is happening in the Arctic? Antarctic and Arctic, convergences & divergences of two international legal systems

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In times of Climate Change, the two poles look closer than ever. In the media and the public discussion, regularly they are covered together and sometimes mistakenly mixed. Nevertheless, of course, they are very different from each other. The Antarctic is a continent covered by ice and surrounded by oceans, while the Arctic is an ocean covered by ice and surrounded by continents. In political and legal terms, although the Antarctic Treaty System is much more developed as international regimen than the Arctic governance agreements, the Arctic seems to be ahead, at least in the sense of the settlements of the geopolitical and economics' controversies between the States that participate in this arena. Even have been proposed that the Antarctic countries should look at what happens with the Svalbard Treaty as an example. Are the Arctic's political and legal present an Antarctic's future? To answer this question, it is necessary to explore the convergences and divergences between the two international legal systems. The presentation will analyse the main elements of this comparison to establish in which sense both poles could evolve in a similar way (and the current Antarctic or Arctic discussions and solutions would be a kind of future to the other) and in which matters they will go necessarily apart. The presentation is bases in and research project done as Research Fellow at the Instituto Complutense de Estudios Internacionales (Spain) during January-March 2020, which is being edited to its publication later this year.

1642

Political realism, political idealism and Antarctic futures

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What should the proper task of a political philosopher be when looking at Antarctica? Should she praise how well the Antarctic Treaty has functioned during 60 years and celebrate it as an exemplar of international cooperation? Should she consider the limitations posed by the claimant states as an in-built factor of Antarctic politics and governance? Should she be looking at the continent as the site of inevitable future confrontations between the “traditional 12” and emerging global geopolitical powers? Or should the political philosopher, instead, criticize the failings of the ATS in becoming a truly global regime? Should she aspire to make Antarctica fit into a larger account of what global justice should look like, enticing her to revisit seemingly “non-negotiable” features of the Antarctic Treaty like frozen sovereignty, and the science criterion for decision-making power?
The question of whether politics should be tackled by philosophers from a realist or an idealist perspective (the first and second above, roughly) has come to the fore in recent years, but no one has yet explored what holding each position implies when thinking about Antarctica’s future. In this presentation, I sketch a preliminary answer and point to my favorite.

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Intersecting Voyages: Inhabitation of Antarctica and Outer Space

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Over the previous two decades, architects have had considerably increased involvement in Antarctica due predominantly to the rise in the number of new stations and the redevelopment of existing stations. Architectural scholarship into the continent has been focused on architecturally historic research and the building performance of stations. Within the emergent and transdisciplinary field of Antarctic futures however a spatial approach from an architectural perspective has been, so far, largely absent. Our speculative research draws from 'design futures' as an architectural practice that moves between spatial design, futures, and fiction. This practice provides a way to think and narrate, or to navigate, Antarctic futures by critically investigating the ground conditions of present human settlement in Antarctica and applying future scenarios informed by extra-terrestrial inhabitation. Speculative storylines of journeys through Antarctica and Outer Space guide our creative exploration into the spatio-temporal parallels and intersections of the two non-sedentary extreme environments including geopolitics and the human body. The presentation of this research takes the form of a hybrid performance space enacted by two individuals and interlaces multiple aspects of storytelling into a singular performance. Antarctic fieldwork and audio-visual media – the real and the imagined, the present and the future – becomes productively intertwined. This performative lecture reveals how a spatial perspective combined with an architectural mode of thinking can break new ground for Antarctic humanities as it proposes a transdisciplinary methodology and creatively contributes to future scenarios of the continent.

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SESSION 48

SPEED TALKS

APECS

ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Subsurface Chlorophyll-a Maxima (SCMs) in the Southern Ocean

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Our review of the literature has revealed Southern Ocean subsurface chlorophyll maxima (SCMs) to be a annually recurrent feature throughout the basin. Most of these SCMs are different to the “typical” SCMs of the tropics, which are maintained by the nutrient-light co-limitation of phytoplankton growth. Rather, we have found SCMs to be more likely formed by diatoms, eddies, sea-ice retreat, photo-acclimation and subduction events. At a local scale, these SCMs can facilitate increased carbon export, primary production and food availability for higher trophic levels.

A large portion of Southern Ocean SCMs appear to be sustained by the presence of deep diatom-dominated communities that form under severe iron-limitation in the upper mixed layer. The ability of diatoms to buoyancy regulate must play a role in the development of these SCMs to facilitate selective sinking after the initial spring bloom or naturally iron fertilised blooms. These SCMs remain largely unobserved and it seems that ship-based sampling may not be able to fully capture the biomass associated with these deep diatom-dominated communities.

The implications of these SCMs for Southern Ocean ecology will only be revealed with their basin-wide observation. This will only be achieved through an integrated observation system that is able to harness the detail of ship-based sampling and the observational capacity of fluorometers on autonomous platforms. The main challenge towards achieving this is the uncertain translatability of fluorescence to chlorophyll-a concentrations. Until this is resolved, the reporting of subsurface fluorescence maxima could still yield valuable insights in SCMs with careful interpretation.

1229

Investigating glacial-isostatic adjustment on basis of geodetic GNSS observation campaigns in Dronning Maud Land, East Antarctica

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Quantifying glacial isostatic adjustment in Antarctica is crucial to understand past and future land and ice-sheet evolution, and to correct estimates of ice-mass change from satellite gravimetry. Direct observables to constrain the GIA modelling are provided by geodetic GNSS measurements on bedrock. In central Dronning Maud Land (DML), East Antarctica, our group started GNSS observation campaigns already in the mid-1990s. The coverage was extended to western DML in 2001/2002 and 2004/2005. Almost all GNSS sites were set up in the mountain range that stretches nearly parallel to the coast over a distance of more than 1,000 km.
Within an ongoing project funded by the German Research Foundation we started to realize repeating GNSS measurements during the last Antarctic season. In the area of Heimefrontfjella six sites were re-measured where first observations were made in 2004/2005. We will discuss the results gained so far for central DML as well as first results for the region of Heimefrontfjella. For this, we applied both the "differential GNSS" (DGNSS) and "precise point positioning" (PPP) method using the Bernese GNSS Software v5.2. Hence, we are able to infer uplift rates for a time span of up to 20 years (central DML) and 15 years (Heimefrontfjella), respectively. We will examine the instantaneous elastic effect which is predicted using time series of ice-mass changes based on multi-mission satellite altimetry (Schröder et al. 2019). Thus, the separation of the instantaneous elastic deformation effect and long-term GIA will be discussed taking recent GIA models into account.

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Electrochemical Regeneration of Granular Activated Carbon and its Opportunities in Water Treatment

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Remediation of contaminated groundwater via adsorption onto Granular Activated Carbon (GAC) has been deployed in Antarctica for nearly two decades. This technology has many advantages including its ability to sorb a wide variety of compounds, from organics to heavy metals, and to host biodegrading bacterial communities. However, one its key disadvantages is its inability to be efficiently regenerated in-situ, with the process occurring over long time periods. Thus requiring it to be dug out and replaced, incurring a human, energy, environmental and financial cost.

Electrochemistry is now being explored as a way to regenerate the adsorptive surface of the carbon; extending its life and reducing the cost of replacement. There are key challenges to overcome before this technology can be deployed on the Antarctic continent including suitable operating conditions, effects on downstream processes and targeting appropriate contaminants of concern. Here we present an overview of the current knowledge base for the technology and its supporting theories, and examine how the process will be scaled up to allow for field deployment.

The deployment of electrochemical regeneration of GAC has the potential to be a key technology in the campaign to restore Antarctica's pristine ecosystem and beauty.

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The European Polar Board – coordinating, promoting and advancing European Polar research

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The European Polar Board (EPB) is an independent organisation focused on major Arctic and Antarctic strategic priorities. EPB Members include European research institutes, government ministries, funding agencies, scientific academies and Polar operators. Since 2015, the EPB has been an independent legal entity, with its Secretariat hosted by the Dutch Research Council (NWO) in The Hague. Established in 1995, the EPB was an Expert Board of the European Science Foundation formed to provide strategic advice on Arctic and Antarctic issues.

The EPB helps to nurture the strong and cohesive European Polar research community, and envisions a European wherein policymaking at different scales affecting or affected by the Polar regions is informed by independent, accurate, and timely advice from the EPB. The EPB's Mission is to improve European coordination of Arctic and Antarctic research by optimising the use of European research infrastructure, to promote multilateral collaborations between our Members, and to provide a single contact point to engage with the European Polar research community.

Much of the EPB's work is conducted through Action Groups. These include the Action Groups on Infrastructure, International Cooperation, and Environmental Impacts of Polar Research and Logistics, and the Policy Advisory Group. In addition, the EPB is engaged in a variety of activities with partner organisations. These include the joint EPB-European Space Agency project CHOICEe, the EPB-APECS webinar series, participation in EU-funded Polar projects such as EU-PolarNet, SO-CHIC and INTERACT III, and as a parter of the EU Polar Cluster.

For more information on the EPB, visit www.europeanpolarboard.org.

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A New Approach: The Syllabus On Polar Regions Towards Education And Outreach

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Over the last decades, global mean temperature keep rising largely due to greenhouse gases which is produced by industrial activities. Global-climate-change has started to have observable effects on the environment not only frost-free season for agriculture, but also polar regions, even double affect on Arctic ocean as ice-melting-feedback loop. Regarding summer temperatures, it is projected to continue rising a reduction of soil moisture in terms of increasing the heat waves. Besides, precipitation patterns, increasing severe weather events will cause the living creatures which are ended up with either forced-migration or forcing into the danger due to lack of food-sources.
Considering rapid dramatically changings on future modellings, researches show that eighteen of the nineteen warmest-years on record for the planet have occured since 2000. On the other hand, it is possible cutting to greenhouse emissions eventually slow down if for instance, the countries take action to decrease their carbon-footprints. In this case, Turkish Students' Polar Research Team(PolSTeam) provides a new view to implement through the schools. Considering global-climate-change and the polar-regions as the best actors in changing, there is a syllabus have prepared including Arctic and Antarctic creatures, sea-ice changes affected by increasing heat wave around the atmosphere, ocean current system and the other parameters to give main idea towards global-climate-change. PolSTeam has already reached over millions of people in order to raise awareness under the education and outreach activities since 2015. This study also will help to understand how the Polar-syllabus impact the students in order to decrease their carbon-footprints.

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