SOOS Symposium

SOUTHERN OCEAN IN A CHANGING WORLD

14–18 AUGUST 2023 | HOBART, TASMANIA

SOOS SYMPOSIUM 2023 INTERNATIONAL PLANNING COMMITTEE

Alessandro Silvano, University of Southampton

Alyce Hancock, Southern Ocean Observing System, University of Tasmania (Convenor)

Andreas Marouchos, Commonwealth Scientific and Industrial Research Organisation

Delphine Lannuzel, Institute for Marine and Antarctic Studies, University of Tasmania

Deneb Karentz, University of San Francisco

Irene Schloss, Instituto Antártico Argentino

Jilda Caccavo, Institute Pierre Simon Laplace

Parli Bhaskar, National Centre for Polar and Ocean Research

Sarat Chandra Tripathy, National Centre for Polar and Ocean Research

Steve Diggs, Scripps Institution of Oceanography

Steve Parker, Commission for the Conservation of Antarctic Marine Living Resources

Sue Cook, Australian Antarctic Program Partnership

Wolfgang Rack, University of Canterbury

Lavenia Ratnarajah, Southern Ocean Observing System, University of Tasmania

SOOS SYMPOSIUM MANAGER

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WELCOME FROM THE CONVENOR

I would like to warmly welcome you to the SOOS Symposium 2023, "Southern Ocean in a Changing World" being held in Hobart, Tasmania. Nipaluna (Hobart), lutruwita (Tasmania) is the land of the Muwinina people and the SOOS Symposium pays their respects to the traditional owners of the land in which the Symposium is being held.

The SOOS Symposium 2023 is the inaugural Symposium of the Southern Ocean Observing System (SOOS). The Symposium theme, "Southern Ocean in a Changing World", recognises the global importance in the Earth system, and is particularly timely with record low levels of sea ice and shifts in critical ocean currents. The Symposium is engaging across the whole Southern Ocean community to enhance coordination and collaboration across all steps in the observational pathway, and provide a forum for assessing our progress so far in providing an observing system that delivers timely and accessible information for the Southern Ocean. The Symposium also provides an opportunity to address the challenges faced in providing long term observations that address policy and societal issues as well as advancing our scientific understanding of the Southern Ocean.

The Symposium program will consist of plenary presentations, panel discussions, parallel sessions, workshops, poster event and trade exhibition. Our keynote speakers will be focused around the eight Symposium themes, incorporating a wide spectrum of Southern Ocean research, the role of new and emerging technologies in driving a step change in Southern Ocean science, and connections to policy and societal challenges.

In addition to the main Symposium program, a number of side-meetings and workshops will be held either side and during the lunch breaks of the SOOS Symposium. These include workshops on Essential Ocean Variables and Observing System Design, open meetings of SOOS's implementation groups, and the annual meetings of SOOS's Scientific Steering Committee and Data Management Sub-Committee.

Located in the heart of Hobart's historic and picturesque waterfront, the SOOS Symposium venue is walking distance from Hobart's sandstone Salamanca precinct and Battery Point heritage cottages, all at the foot of Mt Wellington, kunanyi. As one of the five Antarctic gateway cities, Hobart is a hub for Antarctic, sub-Antarctic and Southern Ocean science, education, research and logistics. We hope you enjoy the scenery, food, culture and history that Hobart has to offer during your visit for the SOOS Symposium.

I would also like to thank all the Symposium sponsors, session convenors, chairs, presenters, the SOOS Scientific Steering Committee, SOOS implementation groups, the Symposium International Planning Committee and symposium manager, Leishman Associates, for their support, hard-work and dedication that has made this momentous Symposium possible.

Alyce Hancock
SOOS Executive Office and SOOS Symposium Convenor

On behalf of the SOOS Executive and Scientific Committees, and the SOOS Symposium 2023 International Planning Committee.

To protect Antarctica and the Southern Ocean is to protect our future on this planet

Every tenth-degree of warming matters. This is the critical decade for decisions to avoid tipping points in Antarctica and the Southern Ocean that affect the entire world.

The Australian Antarctic Program Partnership is a $50 million research program funded for 10 years, from 2019 to 2029.

AAPP improves our understanding of the role of Antarctica and the Southern Ocean within the global climate system and the implications for marine ecosystems.

Through collaborative integrated science and effective communication, our partnership aims to inform impactful and timely policy responses to climate change.

The AAPP is funded by the Australian Government Department of Climate Change, Energy, the Environment and Water through the Antarctic Science Collaboration Initiative.

Find out more at aappartnership.org.au
Follow us @Ant_Partnership

AAPP
Australian Antarctic Program Partnership

The Australian Antarctic Program Partnership is led by the University of Tasmania, and includes the following partner agencies

University of Tasmania IMAS Institute for Marine and Antarctic Studies

Australian Government Department of Climate Change, Energy, the Environment and Water Australian Antarctic Division

Australian Antarctic Program

CSIRO

Australian Government Bureau of Meteorology

IMOS Integrated Marine Observing System

Australian Government Geoscience Australia

Tasmanian Government

Photo: Esmee van Wijk

PROGRAM: MONDAY 14 AUGUST

0700 – 1730	**Registration Open** – Mezzanine Foyer
	Grand Ballroom

Symposium Opening
Chair: Dr Alyce Hancock, Executive Officer SOOS

0830 – 0900

Dr Alyce Hancock, Executive Officer SOOS

The Hon Sir Guy Green

Patron of Antarctic Tasmania, former Governor of Tasmania and Honorary Antarctic Ambassador

Born in Launceston in 1937, Guy Green studied Law at the University of Tasmania and after being admitted to the bar in 1960, practised in Launceston. Intelligent, congenial, conciliatory and highly respected, an enthusiastic promoter of Tasmania, Guy Green was an obvious candidate for high office.

Welcome to Country

Auntie Brenda

0900 – 0930

Welcome from SCAR and SCOR

Yeadong Kim, SCAR President

Emily Twigg, SCOR Executive Director

Need for a Southern Ocean Observing System
Chair: Dr Alyce Hancock, Executive Officer SOOS

0930 – 1000

Steve Rintoul

CSIRO, Australia

Dr Stephen R. Rintoul AO AAM FAA is a physical oceanographer and climate scientist at CSIRO Environment and the Australian Antarctic Program Partnership in Hobart. His research is focused on the role of the ocean in the climate system.

1000 – 1030

SOOS: Current activities and contribution to Southern Ocean Research

Prof Eileen Hofmann

Old Dominion University, USA

Eileen Hofmann is Professor and Eminent Scholar in the Department of Ocean and Earth Sciences and a member of the Center for Coastal Physical Oceanography at Old Dominion University. Her research on understanding physical-biological interactions in marine ecosystems was recognized by her election as Fellow of the American Geophysical Union.

1030 – 1100	**Morning Refreshments**

PROGRAM: MONDAY 14 AUGUST

1100 – 1230	**Creating impact for your observational data beyond research - Workshop**	**Southern Ocean sea ice variability in a warming climate: observations and modeling approach**	**Human Engagement with the Southern Ocean: Science, Tourism, Environment**
	Grand Ballroom 1	**Grand Ballroom 2**	**Grand Ballroom 3**
	Chair: Alyce Hancock	Chairs: Petra Heil, Marcello Vichi	Chairs: Hanne Nielsen, Elizabeth Leane
1100 – 1115	**Creating impact for your observational data beyond research** **Workshop**	**Increased Antarctic sea ice variability and its drivers** **Dr Will Hobbs** Australian Antarctic Program Partnership	**Citizen Science in the Southern Ocean: Tourist Perspectives** **Dr Hanne Nielsen** University of Tasmania
1115 – 1130		**An abrupt transition in Antarctic sea ice–ocean system** **Alexander Haumann** Alfred Wegener Institute / Ludwig-Maximilian-University Munich	**Public Support for Antarctic and Southern Ocean Science in Australia: Lessons from a National Survey** **Prof Elizabeth Leane** University of Tasmania
1130 – 1145		**Is the Antarctic sea ice already sweating? A glimpse into recent in-situ ice and snow data in the Weddell Sea** **Dr Stefanie Arndt** Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung	**FjordPhyto: A citizen science project that enriches travelers experience in Antarctica** **Allison Cusick** Scripps Institution of Oceanography
1145 – 1200		**Measuring up: Antarctic sea ice in the Earth system** **Dr Petra Heil** AAD & AAPP, University of Tasmania	**Stories of the far south: Why Antarctica needs an intersectional lens.** **Kimberly Aiken** University of Tasmania
1200 – 1215		**The complexities of estimating sea-ice production from field observations with implications for model-based estimates and for ice-climate and ice-ecosystem interactions** **Dr Sharon Stammerjohn** University of Colorado Boulder	**From historical humpback whale catch data to climate model evaluations in the Southern Ocean** **Prof Marcello Vichi** University of Cape Town
1215 – 1230		**East Antarctic Coastal Current and its influence on summertime sea ice distribution** **Dr Phil Reid** Australian Bureau of Meteorology	**Updates on the SCAR Antarctic Biodiversity Portal GBIF Hosted Portal** **Dr Anton Van De Putte** Royal Belgian Institute for Natural Sciences/ Université Libre de Bruxelles

Hybrid offering

PROGRAM: MONDAY 14 AUGUST

1230 – 1330	**Lunch** **West Antarctic Peninsula and Scotia Arc Regional Working Group Meeting**		
1330 – 1530	**Creating impact for your observational data beyod research & How to in SOOSmap**	**Plankton Diversity, food web dynamics and biogeochemical cycle in the Southern Ocean**	**Observations to understand ocean dynamic processes**
	Grand Ballroom 1	**Grand Ballroom 2**	**Grand Ballroom 3**
	Chair: Alyce Hancock	Chairs: Sarat Chandra Tripathy, Ruth Eriksen, Toru Hirawake, Kazuhiro Yoshida, Kerrie Swadling, Luke Brokensha	Chairs: Helen Phillips, Annie Foppert, Laura Herraiz-Berreguro
1330 – 1345	**Creating impact for your observational data beyond research** **Workshop**	**Physical-biological drivers modulating phytoplankton seasonal succession along the Northern Antarctic Peninsula** **Raul Rodrigo Costa** FURG	**Observational evidence of cold filamentary intensification in an energetic meander of the Antarctic Circumpolar Current** **Maya Jakes** IMAS, University of Tasmania
1345 – 1400		**The effect of iceberg melt on nutrient stoichiometry and primary producers** **Dr Mark Hopwood** SUSTech	**Physical controls on ventilation and air-sea exchange in Drake Passage** **Lilian Dove** Caltech
1400 – 1415		**Plankton diversity and dynamics in the upper surface of the Indian sector of Southern Ocean ecosystem: biogeochemical implications** **Athirpankandi Sreerag** National Centre for Polar and Ocean Research	**Mixing and water mass modification over Discovery Bank, in the Weddell Scotia Confluence of the Southern Ocean** **Dr Alexander Brearley** British Antarctic Survey
1415 – 1430		**Inter-annual variability of POM dynamics and its implications on the biological pump in the Indian sector of the Southern Ocean** **Dr Melena Soares** National Centre for Polar and Ocean Research	**How much Upwelling occurs in the Abyssal Bottom Boundary Layer?** **Emeritus Professor Trevor McDougall** University of New South Wales

Hybrid offering

1430 – 1445		**Macrozooplankton food-webs across the South Georgia shelf region, and their relationship to Antarctic krill abundance** **Anona Griffiths** Imperial College London	**Revisiting circulation and water masses over the East Antarctic margin (80-150°E)** **Dr Kaihe Yamazaki** Institute for Marine and Antarctic Studies, University of Tasmania
1445 – 1500	**How to in SOOSmap** **Workshop**	**Diversity patterns of prokaryotic communities in the Scotia Sea and Bransfield Strait during summer 2019** **Mireia Mestre** Museo Nacional de Ciencias Naturales (MNCN-CSIC)	**Diapycnal and isopycnal mixing along the continental rise in the Australian–Antarctic Basin** **Dr Katsuro Katsumata** JAMSTEC
1500 – 1515		**Risks of Poleward Expansion of Harmful Dinoflagellates in the Southern Ocean** **Dr Ji Li** Shanghai Jiao Tong University	**Seasonal overview of oceanography and AABW formation in the Cape Darnley region, Antarctica** **Sienna Blanckensee** The University of Queensland
1515 -1530		**Microplastic studies in the coastal waters of South Australia** **Anastasiia Snigirova** Flinders University	**Tracing Antarctic freshwater from the grounding zone to the ice front in the Ross Embayment** **Matthew Siegfried** Colorado School of Mines
1530 – 1600	**Afternoon Refreshments**		

Circumpolar observations and programmes

Chair: Irene Schloss, Austral Center for Scientific Research (CADIC-CONICET), Argentinian Antarctic Institute, National University of Tierra del Fuego

1600 – 1700 **Andrew Meijers**

British Antarctic Survey, UK

Andrew Meijers is a physical oceanographer at the British Antarctic Survey. He specialises in the large-scale ocean circulation and change around Antarctica, using both observations and climate models. Hailing from Tasmania, he undertook his PhD at the University of Tasmania.

1730 – 1930 **Early Career Networking Event**

Tasmanian Museum and Art Gallery

Early career attendees are invited to bring an invited guest to a networking event at the Tasmanian Museum and Art Gallery.

Proudly sponsored by TMAG

TASMANIAN MUSEUM & ART GALLERY

Hybrid offering

0800 – 1730 **Registration Open** – Mezzanine Foyer

Grand Ballroom

Regional observations and programmes

Chair: Juan Hofer, Pontificia Universidad Catolica De Valparaiso

0830 – 0930 **Prof Oscar Schofield**

Rutgers University, USA

Oscar M.E. Schofield, is a distinguished professor and the chair of the Department of Marine and Coastal Sciences at Rutgers, The State University of New Jersey. He is interested in how plankton dynamics structure marine food webs and feedback on the ocean's biogeochemistry.

Equity, Diversity and Inclusion in Southern Ocean Research

Chair: Steve Diggs, University of California San Diego

0930 – 0945 **Kimberly Aiken**

University of Tasmania

Kimberly is a PhD student at UTAS, Institute for Marine and Antarctic Studies, undertaking a research project focused on building more diverse, equitable, and inclusive extreme and remote workforces with lessons from Antarctica, Outer Space and Underground Mining using intersectionality to examine overlapping identities such as race and gender to promote recruitment and retention of historically underrepresented groups.

0945 – 1000 **Angus Aldis**

Accessibility In Polar Research

Navigating polar science is tricky, especially for researchers with disabilities. Issues persist that disqualify researchers with disabilities from pursuing their dreams. To address this, Accessibility in Polar Research (APR/@accesspolar) was founded during the pandemic by a small group of researchers with disabilities.

1000 – 1015 **Dani Jones**

British Antarctic Survey

Dr Dani Jones is a Physical Oceanographer and a UKRI Future Leaders Fellow at the British Antarctic Survey. Their research focuses on using numerical modeling (including adjoint modeling) and unsupervised classification to gain insight into ocean structure and dynamics.

1015 – 1030 **Alex Thornton**

Pride in Polar Research

Alex Thornton is the founder of Pride in Polar Research (PiPR), a global, volunteer-run group that supports, uplifts, and creates community for those with minority LGBTQIA+ identities in polar science. As an openly queer, intersex, and disabled marine scientist and educator from an international, multicultural family, he is deeply committed to creating access and equity for underrepresented communities in STEM, particularly for those at the intersectionality of marginalization.

Panel: Kimberly Aiken, Angus Aldis, Dani Jones, Alex Thornton and Lydi Keppler, Scripps Institution of Oceanography

PROGRAM: TUESDAY 15 AUGUST

1030 – 1100	**Morning Refreshments**		
1100 – 1300	**New insights and cross-disciplinary observing requirements for (circum-)Antarctic sea-ice processes**	**Regional ocean observing and modelling system developments in the Ross Sea sector**	**Distributed research efforts from the Scotia Arc through the West Antartic shelf seas**
	Grand Ballroom 1	**Grand Ballroom 2**	**Grand Ballroom 3**
	Chairs: Sian Henley, Klaus Meiners, Petra Heil, Marc Mallet, Marcello Vichi	Chairs: Craig Stevens, Minkyoung Kim, Zhaomin Wang, Denise Fernandez	Chairs: Andy Thompson, Pierre Dutrieux, Oscar Schofield, Juan Hofer
1100 – 1115	**Remotely-sensing the wave-affected Antarctic marginal ice zone using pulse-limited radar altimeters** **Dr Alexander Fraser** Australian Antarctic Program Partnership	**A Conceptual Model for a U.S. Ross Sea Internationally Coordinated Research Network** **Dr Sharon Stammerjohn** University of Colorado Boulder	**Atmospheric forcing of interannual variability in Amundsen Sea basal melt rates** **Ole Rieke** Institute for Marine and Antarctic Studies, University of Tasmania
1115 – 1130	**Wave-Affected Marginal Ice Zones in Southern Ocean from Satellite Altimeters – A Study of the Indian Sector in July, 2017** **Dr Shiming Xu** Tsinghua University	**Connection of Dense Shelf Water Variability in the Western Ross Sea to the Southern Annular Mode** **Dr Zhaoru Zhang** Shanghai Jiao Tong University	**Ecological Response to "Press-Pulse" Disturbances Along a Rapidly Changing West Antarctic Peninsula** **Prof Oscar Schofield** Rutgers University
1130 – 1145	**Waves and sea-ice in the Marginal Ice Zone: from observations to model** **Joey Voermans** University of Melbourne	**Heat and water masses distribution in the Ross Sea from observations and model simulations** **Denise Fernandez** National Institute Of Water and Atmospheric Research (NIWA)	**FjordPhyto, a citizen science platform that enhances spatial and temporal coverage of nearshore phytoplankton research on the Antarctic Peninsula** **Martina Mascioni** Universidad Nacional De La Plata
1145 – 1200	**A novel system for quantitative sampling of sub-ice platelet layers** **Natalie Robinson** NIWA	**The salinity budget of the Ross Sea continental shelf, Antarctica** **Liangjun Yan** Hohai University/NIWA	**Small scale bottom up controls of foraging behavior in a biological hotspot** **Dr Matthew Oliver** University of Delaware

Hybrid offering

PROGRAM: TUESDAY 15 AUGUST

1200 – 1215	**Using historical data compilations and novel methods to improve observational coverage of Southern Ocean sea-ice biogeochemical properties** **Dr Klaus Meiners** Australian Antarctic Division	**The Terra Nova Bay Polynya activity in the new coupled model Polar-SKRIPSv1** **Dr Alena Malyarenko** NIWA	**Quantifying Physical Prey Concentrating Features in Palmer Deep, Antarctica** **Jacquelyn Veatch** Rutgers University
1215 – 1230	**An international circumpolar compilation of macronutrient concentrations in Antarctic land-fast sea ice: science highlights and open access data** **Dr Sian Henley** University of Edinburgh	**Controls of topographic Rossby wave properties and downslope transport in dense overflows** **Prof Zhaomin Wang** Southern Marine Science and Engineering Guangdong Laboratory (zhuhai)	**Examining the Connectivity of Antarctic Krill on the West Antarctic Peninsula: Implications for Pygoscelis Penguin Biogeography and Population Dynamics** **Dr Katherine Gallagher** Stony Brook University
1230 – 1245	**Is marginal sea ice a source of Fe and impacts productivity in South Atlantic?** **Prof Alakendra Roychoudhury** Stellenbosch University	**Observing ice shelf ocean cavity hydrography: The Ross Ice Shelf** **Prof Craig Stevens** NIWA/University of Auckland	**Are biological hotspots farms or markets? The importance of resource retention for maintaining an Antarctic biological hotspot.** **Dr Matthew Oliver** University of Delaware
1245 – 1300	**Seasonal cycling of Fe in the marginal ice zone of Southern Ocean around zero meridian: linkage to phytoplankton bloom** **Dr Saumik Samanta** Stellenbosch University	**Phytoplankton seasonal cycle and carbon export in the Ross Sea: A modeling study** **Prof Eileen Hofmann** Old Dominion University	
1300 – 1400	**Lunch** **Weddell Sea and Dronning Maud Land Regional Working Group Meeting** **Southern Ocean Indian Sector Regional Working Group Meeting**		

Hybrid offering

1400 – 1530	Southern Ocean sea ice variability in a warming climate: observations and modeling approach	Regional ocean observing and modeling system developments in the Ross Sea sector	Observing, mapping and monitoring Antarctic, seafloor fauna and their habitat
	Grand Ballroom 1	**Grand Ballroom 2**	**Grand Ballroom 3**
	Chairs: Petra Heil, Marcello Vichi	Chairs: Craig Stevens, Minkyoung Kim, Zhaomin Wang, Denise Fernandez	Chairs: Jan Jansen, Nicole Hill
1400 – 1415	**Does the recent decline in Antarctic sea ice indicate a climate shift? Insights from satellite observations,Argo floats, and model reanalysis** **Kshitija Suryawanshi** National Centre for Polar and Ocean Research	**Summer physical and biogeochemical conditions in Ross Sea polynya from glider data** **Esther Portela Rodriguez** University of East Anglia	**The International Bathymetric Chart of the Southern Ocean** **Patrick Schwarzbach** Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
1415 – 1430	**Novel model of sea ice growth to improve observing system for Antarctic polynyas** **Dr Igor Appel** TAG	**Observing zooplankton and Antarctic silverfish in the Ross Sea** **Dr Svenja Halfter** NIWA	**A circumpolar benthic bioregionalisation for the Antarctic continental shelf derived from seafloor imagery** **Dr Nicole Hill** University of Tasmania/ Institute for Marine and Antarctic Studies
1430 – 1445	**Variability and trends of the Antarctic marginal ice zone** **Prof Marcello Vichi** University of Cape Town	**The net community production and phytoplankton community changes at the Ross Sea** **Prof Yonghui Gao** Shanghai Jiaotong University	**The circum-Antarctic distribution of seafloor biodiversity: Identifying hotspots of seafloor biodiversity and priorities for future research cruises** **Jan Jansen** University of Tasmania
1445 – 1500	**Antarctic snow depth, ice thickness and ice volume variability in the context of the 2022 and 2023 record minimum extent** **Dr Sahra Kacimi** Jet Propulsion Laboratory	**Spatio-temporal variation of glacial meltwater and its influences on the continental shelf region of the Ross Sea** **Prof Seung-Tae Yoon** Kyungpook National University	**Identifying Vulnerable Marine Ecosystems in the Southern Ocean: circumpolar model prediction and vulnerability index quantification** **Charley Gros** Institute for Marine and Antarctic Studies, University of Tasmania

Hybrid offering

Time			
1500 – 1515	**Polardex/DueSouth** **Workshop**	**Long-term moored observations of export and exchange from the northwestern Ross Sea** **Dr Melissa Bowen** University of Auckland	**The muddy road to forecast distribution patterns of polychaete communities (taxonomic and functional groups) on the Weddell Sea Shelf** **Friederike Weith** University of Rostock
1515 – 1530		**Sea Surface Height Signature of the Dense Water Overflows in the Ross Sea** **Paul Spence** University of Tasmania	
1530 – 1600	**Afternoon Refreshments**		

Data Systems
Chair: Petra ten Hoopen, UK Polar Data Centre, BAS

1600 – 1700 **Vito Vitale (Virtual)**
CNR Institute of Polar Sciences, Italy

Vito Vitale is Research Director at the CNR Institute of Polar Sciences (ISP) in Bologna. He has been involved in polar research and management since 1986, both in Antarctica and in the Arctic. He is an expert of radiative transfer processes into the atmosphere.

1700 – 1830 **Poster Session**
Federation Ballroom
Authors will stand by their poster for the duration of this session to answer questions and discuss.
Proudly sponsored by the Tasmanian Polar Network

Photo Credit: Anna Wahlin

0800 – 1730	**Registration Open** – Mezzanine Foyer		
	Grand Ballroom		
Impact of observations in policy and societal challenges Chair: Sian Henley, University of Edinburgh & Jilda Caccavo, Institute Pierre-Simon Laplace			
0830 – 0930	**Indi Hodgson-Johnston** ARC Australian Centre for Excellence In Antarctic Science, Australia Indi is the ACEAS Chief Operating Officer and is an Adjunct Senior Researcher in Antarctic and oceans law and policy at the Institute for Marine and Antarctic Studies at the University of Tasmania. She also works as a rapporteur at the Antarctic Treaty Consultative Meetings, and is Senior Deputy Chair of the Tasmanian Polar Network Executive. 		
0930 – 1000	**Panel: Indi Hodgson-Johnston (ARC Australian Centre for Excellence In Antarctic Science), Tony Press (IMAS, University of Tasmania) & Mary-Anne Lea (IMAS, University of Tasmania)**		
1000 – 1030	**Morning Refreshments**		
1030 – 1230	**Emerging technologies enabling future Southern Ocean observations**	**Understanding the state and variability of Southern Ocean CO2 sea-air fluxes and carbon cycle**	**How Argo is transforming our understanding of the Southern Ocean in the global climate**
	Grand Ballroom 1	**Grand Ballroom 2**	**Grand Ballroom 3**
	Chairs: Andreas Marouchos, Hui Sheng Lim, Christopher Moony, Oscar Schofield, Joellen Russell, Patrick Gorringe, Tommy Bornman, Juliet Hermes, Antonio Novellino	Chairs: Xiang Yang, Cathryn Wynn-Edwards, Elizabeth Shadwick	Chairs: Christina Schallenberg, Bea Pena-Molino, Annie Foppert, Laura Herraiz-Borreguero
1030 – 1045	**Autosub Long Range vehicle 12 month deployment for the NERC Drivers of Oceanic Change in the Amundsen Sea (DeCAdeS) project** **Matthew Kingsland** National Oceanography Centre	**Assessing decadal anthropogenic carbon dioxide changes in the Ross Sea with stable carbon isotope measurements** **Dr Keyhong Park** Korea Polar Research Institute	**Polar Argo: current state, science highlights and technological advances** **Esmee van Wijk** CSIRO Environment
1045 – 1100	**Toothfish fishing vessels as vessels of opportunity** **Rhys Arangio** COLTO	**Drivers of Marine CO2-Carbonate Chemistry in the Northern Antarctic Peninsula** **Thiago Monteiro** FURG	**Observing dense shelf water in the ice-covered western Weddell Sea with intentionally-grounded Argo floats** **Dr Markus Janout** Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

Hybrid offering

1100 – 1115	**Ocean properties and variability in front and beneath the Dotson Ice Shelf: direct observations from autonomous gliders and float profilers** **Dr Pierre Dutrieux** British Antarctic Survey	**Constraining the mechanisms of Southern Ocean dissolved iron distributions along GO-SHIP transect SR3 using optimum multiparameter analysis** **Christopher Traill** IMAS-AAPP	**Properties and pathways of Antarctic Bottom Water from five years of Deep Argo in the Australian-Antarctic Basin** **Dr Annie Foppert** AAPP
1115 – 1130	**Adaptive information gathering in the Southern Ocean using a team of autonomous vehicles** **Dr Hui Sheng Lim** Commonwealth Scientific and Industrial Research Organisation (CSIRO)	**Interaction between multiple physical particle injection pumps and the impact on carbon export in the Southern Ocean** **Dr Andrew Thompson** California Institute of Technology	**Antarctic sea ice formation and melt rates estimated from under-ice Argo observations** **Ethan Campbell** University of Washington
1130 – 1145	**An array of in situ waves-in-ice instruments deployed during targeted observational experiment in winter 2022 in the Antarctic MIZ** **Robyn Verrinder** University of Cape Town	**Exploring the euphotic zone residence time for lower cell water mass** **Yinghuan Xie** UTAS IMAS	**The drivers of Winter Water's spatiotemporal variability over the annual cycle** **Theo Spira** University of Gothenburg
1145 – 1200	**Enabling Science with a Subsea Fiber Optic Cable for McMurdo Station, Antarctica** **David Porter** National Science Foundation	**A meta-analysis of studies comparing profiling float pCO2 estimates with independent observations** **Dr Kenneth Johnson** MBARI	**Poleward shift of Circumpolar Deep Water threatens the East Antarctic Ice Sheet** **Laura Herraiz Borreguero** CSIRO
1200 – 1215	**SMART Cables potential for the National Tsunami Warning Centers** **Matias Sifon** Servicio Hidrografico Y Oceanografico De La Armada De Chile	**The Southern Ocean Carbon Gas Observatory (SCARGO) : an airborne platform for improving observational constraints on Southern Ocean CO2 fluxes** **Jesse Vance** NCAR | UCAR	**An updated Gravest Empirical Mode climatology – utilising the wealth of Southern Ocean observations** **Nathan Bindoff** Institute for Marine and Antarctic Studies

PROGRAM: WEDNESDAY 16 AUGUST

1215 – 1230	**Observing the Ocean and Earth with SMART Subsea Cables** **Ceci Rodriguez** Joint Task Force Smart Cable	**Preliminary Results from the International Nutrient Inter-Comparison Voyage: Reducing Uncertainty in at-sea Nutrient Measurements** **Dr Harris Anderson** CSIRO	**Insight into Southern Ocean eddies from Historical observations** **Dr Ramkrushnbhai Patel** University of Tasmania
1230 – 1330	**Lunch** **Ross Sea Land Regional Working Group Meeting**		
1330 – 1530	**Emerging technologies enabling future Southern Ocean observations / Reshaping long-term observatories with focus on Antarctic and Southern Ocean: drivers, implementation and outcome**	**Observations to improve predictions of Southern Ocean ecosystems in the global context**	**How Argo is transforming our understanding of the Southern Ocean in the global climate**
	Grand Ballroom 1	**Grand Ballroom 2**	**Grand Ballroom 3**
	Chairs: Petra Heil, Anna MacDonald, Julie McInnes	Chairs: Stuart Corney, Eileen Hofmann, David Green	Chairs: Christina Schallenberg, Bea Pena-Molino, Annie Foppert, Laura Herraiz-Borreguero
1330 – 1345	**Simulating phytoplankton movement within the surface mixed layer to characterise the Southern Ocean spring bloom onset** **Tamara Schlosser** University of Tasmania – ACEAS	**KRILLPODYM: a mechanistic, spatially resolved model of Antarctic krill distribution and abundance** **Dr David Green** IMAS University of Tasmania	**SOCCOM (Southern Ocean Carbon and Climate Observations and Modeling): Biogeochemical Argo, State Estimation and Earth System Modeling** **Professor Lynne Talley** Scripps Institution of Oceanography, UCSD
1345 – 1400	**Using Ship-Deployed High-Endurance Uncrewed Aerial Vehicles for the Study of Ocean/Ice Surface and Atmospheric Boundary Layer Processes** **Christopher J Zappa** Lamont-Doherty Earth Observatory of Columbia University	**Krill Growth Rates and Environmental Drivers in the Southern Ocean: Implications for Ecosystem Management and Sustainability** **Jessica Melvin** Institute for Marine and Antarctic Studies, University of Tasmania	**Southern Ocean Biological Response to Dust Quantified by BGC-Argo Observations** **Jakob Weis** IMAS

Hybrid offering

1400 – 1415	**The Southern Ocean Time Series – what can we learn from a decade of deep-water mooring observations?** **Dr Elizabeth Shadwick** CSIRO	**Decadal timeseries of animal tracking, isotopes and biogeochemical modelling to simulate regional ecosystem variability in the Southern Ocean** **Professor Mary-Anne Lea** IMAS, University of Tasmania	**Sea Surface Kinetic Energy as a Proxy for Phytoplankton Light Limitation in the Summer Pelagic Southern Ocean** **Dr Matthew Oliver** University of Delaware
1415 – 1430	**Autonomous ocean-sea ice-atmosphere observatory for the Southern Ocean** **Dr Petra Heil** AAD & AAPP, University of Tasmania	**Lessons from the Marine Ecosystem Assessment for the Southern Ocean (MEASO) on measuring biological "sentinel" variables to support decision making** **Andrew Constable** University of Tasmania	**What lies beneath? Deep diatom communities are observed across the Southern Ocean** **Kimberlee Baldry** University of Tasmania
1430 – 1445	**The South African Polar Research Infrastructure** **Prof Juliet Hermes** South African Environmental Observation Network	**Satellite products and services for collection and delivery of essential observations of the Southern Ocean** **Oliver Palin** CLS Oceania	**The Effects of Mesoscale Eddies on Southern Ocean Biogeochemistry** **Dr Lydi Keppler** Scripps Institution of Oceanography
1445 – 1500	**Macquarie Island Wildlife Monitoring Program: strategic monitoring for applied conservation and management** **Kris Carlyon** Department of Natural Resources and Environment Tasmania	**The Humpback Whale Sentinel Programme; Biomonitoring for Ecosystem and Chemical Surveillance** **Prof Susan Bengtson Nash** Griffith University	**Southern Ocean Acidification Revealed by Biogeochemical-Argo Floats** **Ariane Verdy** Scripps Institution of Oceanography, UCSD
1500 – 1515	**Bringing together approaches to reporting on within-species genetic diversity** **Dr Anna Macdonald** Australian Antarctic Division	**Using satellites to monitor catastrophic breeding failures at emperor penguin colonies linked to historic low sea ice extents** **Dr Peter Fretwell** British Antarctic Survey	**Subantarctic pCO_2 estimated from a biogeochemical float: comparison with moored observations reinforces the importance of spatial and temporal variability** **Dr Cathryn Wynn-Edwards** CSIRO, AAPP, IMAS

Hybrid offering

1515 – 1530	**DNA-based diet analysis of subantarctic predators to assess Southern Ocean food-web linkages and ecosystem change** **Dr Julie McInnes** Institute for Marine and Antarctic Studies	**Modelling the krill-centred ecosystem: how far can we push it?** **Dr Stuart Corney** Institute for Marine and Antarctic Studies	**Under-ice Float Observations from the SOCCOM Array: Examples and Climatologies** **Dr Stephen Riser** University of Washington
1530 – 1600	**Afternoon Refreshments**		

New observing technology and systems in Southern Ocean observations
Chair: Andreas Marouchos, CSIRO

1600 – 1700 **Noah Lawrence-Slavas**

National Oceanic and Atmosphere Administration (NOAA), USA

Noah Lawrence-Slavas is the principle mechanical engineer for the NOAA's Pacific Marine Environmental Laboratory where he leads diverse engineering teams, collaborating with principle scientific investigators, to innovate and develop new tools for scientific research.

1830 – 2300 **Symposium Dinner**

Franklin Wharf Function Centre

Pre-booking required. If you have purchased a ticket, it will be noted on your name badge. Franklin Wharf is a short 5 minute scenic walk from the Symposium Venue along Hobart's waterfront, a working port and home to the Antarctic icebreaker, Nuyina. After the Symposium dinner, you can continue enjoying Hobart's hospitality at the adjacent restaurant/bar precinct Salamanca.

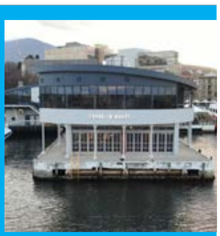


Photo Credit: Angelika Brandt:Buckelkopf

Hybrid offering

0900 – 1800	**Registration Open** – Mezzanine Foyer
	Grand Ballroom

Southern Ocean in the Global UN Ocean Decade
Chair: Eileen Hofmann, Old Dominion University

0930 – 0944 **Alison Clausen (Virtual)**
Intergovernmental Oceanographic Commission of UNESCO

Alison Clausen is the Deputy Global Coordinator of the UN Decade of Ocean Science for Sustainable Development at IOC-UNESCO. She joined IOC as a programme specialist in 2019 with over twenty-five years' professional experience in program and project development and management in the areas of marine conservation, marine policy, and climate change adaptation.

0944 – 0958 **Renuka Badhe**
European Polar Board, Netherlands

As a knowledge broker with a background in oceanography, economics and public policy, she has longstanding expertise working with a wide range of international organisations and projects at the interface of science, policy and/or strategy development or overlaps thereof.

0958 – 1012 **Anton Van de Putte**
Royal Belgian Institute of Natural Sciences, Belgium

Dr Anton Van de Putte is a marine biologist and open science advocate who obtained a PhD from the KULeuven working on the ecology and evolution of Antarctic fish. During his PhD he developed a strong interest in the Antarctic treaty system and it's spirit of cooperation.

1012 – 1026 **Stuart Corney**
Institute for Marine and Antarctic Studies, University of Tasmania, Australia

Dr Stuart Corney is a senior lecturer and Associate Head Learning and Teaching at the Institute for Marine and Antarctic Studies at the University of Tasmania. Stuart's research focuses on the interface between the physical environment and ecosystem dynamics.

1026 – 1040 **Karen Evans**
CSIRO, Australia

Dr Evans is a principal research scientist and team leader with CSIRO Oceans and Atmosphere based in Hobart, Tasmania. Her projects deliver strategic research to national agencies, regional programmes in the Pacific and Indian Oceans and international agencies, including the United Nations.

1040 – 1130 **Panel: Renuka Badhe, Anton Van de Putte, Stuart Corney, Karen Evans and Sian Henley (University of Edinburgh, United Kingdom)**

Hybrid offering

1130 – 1230	**Lunch** **Southern Ocean Air-Sea Fluxes Capability Working Group Meeting** **Censusing Animal Populations from Space Capability Working Group Meeting**		
1230 – 1445	**Southern Ocean plankton: productivity, diversity, food-web dynamics, time-series & biogeochemistry**	**Air-sea interactions and climate variability in the Southern Ocean**	**Circumpolar Antarctic Ice Sheet-Ocean observations: towards an integrated view and improved climate models**
	Grand Ballroom 1	**Grand Ballroom 2**	**Grand Ballroom 3**
	Chairs: Sarat Chandra Tripathy, Ruth Eriksen, Toru Hirawake, Kazuhiro Yoshida, Kerrie Swadling, Luke Brokensha	Chairs: Marcel du Plessis, Luciano Pezzi	Chairs: Andrew Meijers, Markus Janout, Felicity McCormack, Sue Cook, Pierre Dutrieux
1230 – 1245	**Under-ice phytoplankton in autumn uncovered by southern elephant seals in the East Antarctic** **Laura Dalman** University of Tasmania	**Impact of a melting 'megaberg' on water column hydrography in the Southern Ocean** **Dr Alexander Brearley** British Antarctic Survey	**Antarctic RINGS to characterise the Antarctic Ice Sheet coastal zone and Antarctica's contribution to sea-level rise** **Dr Felicity McCormack** Monash University
1245 – 1300	**Trends in Southern Ocean phytoplankton iron stress, primary production and bloom phenology** **Dr Sandy Thomalla** CSIRO	**High Salinity Shelf Water production in Terra Nova Bay, Ross Sea from high-resolution near-surface salinity observations** **Christopher J Zappa** Lamont-Doherty Earth Observatory of Columbia University	**NECKLACE: Collating a circum-Antarctic dataset of ice shelf basal melt** **Dr Sue Cook** AAPP
1300 – 1315	**Variations in the particle size distribution and chlorophyll-to-carbon ratio in the Southern Ocean** **Juan Li** Curtin University	**Long term spatiotemporal trends in chlorophyll-a and sea surface salinity in Southern Ocean and their association with aerosol nutrients** **Dr Salman Tariq** University of the Punjab	**Western Ross Sea ice tongues sentinels of oceanographic change** **Rodrigo Gomez Fell** University of Canterbury
1315 – 1330	**Bottom-up controls on summer phytoplankton dynamics in the surface waters of the Gerlache-Bismarck Strait area, Western Antarctic Peninsula** **Dr Juan Höfer** Pontificia Universidad Catolica De Valparaiso	**High-resolution thermal imaging in the Antarctic Marginal ice zone: Ocean skin heterogeneity and effects on heat fluxes** **Ippolita Tersigni** The University of Melbourne	**Subglacial freshwater drainage increases simulated basal melt of the Totten ice shelf** **Dr David Gwyther** University of Queensland

Hybrid offering

1330 – 1345	**Low-Fe availability reduces the photosynthetic competency of ice algae upon discharge from sea ice** Dr Kazuhiro Yoshida Saga University	**Water mass and heat flux exchanges between the Southern Ocean and Antarctic seas, East Antarctica** Dr Libao Gao First Institute of Oceanography	**Seafloor roughness reduces melting of the Antarctic ice sheets** Yuhang Liu University of Tasmania
1345 – 1400	**Contrasting phytoplankton communities between Cape Darnley and Dalton Polynyas, off East Antarctica, during sea-ice melting and forming seasons** Dr Keigo Takahashi Soka University	**ACC Meanders Enhance Air-Sea Heat Flux Exchange and Water Subduction** Felipe Vilela-Silva UTAS, CLEX, AAPP	**Internal tsunamigenesis and ocean mixing driven by glacier calving in Antarctica** Dr Alexander Brearley British Antarctic Survey
1400 – 1415	**Bio-optical Depiction of a Polar Ocean Under Global Change: Exploring the Regional Absorption Traits** Dr Sarat Chandra Tripathy National Centre for Polar and Ocean Research (NCPOR)	**Summer upper ocean warming controlled by storms in the subpolar Southern Ocean** Dr Marcel Du Plessis University of Gothenburg	**Sea ice – ocean – land ice: interacting processes in the western Ross Sea observed by airborne geophysics** Prof Wolfgang Rack University of Canterbury
1415 – 1430	**Living on the edge: response of deep phytoplankton communities to light, iron and manganese additions** Dr Pauline Latour ACEAS, UTAS	**Storm's role for air-sea CO2 exchange in the Southern Ocean** Magdalena Carranza Monterey Bay Aquarium Research Institute	**A connected circulation system of the West Antarctic shelf seas** Dr Andrew Thompson California Institute of Technology
1430 – 1445		**An ensemble-based Data Assimilation System for the Southern Ocean (DASSO)** Prof Qinghua Yang Sun Yat-sen University	**Poleward transport of mCDW mediated by standing eddies in Southern Ocean Indian Sector** Dr Kohei Mizobata Tokyo University of Marine Science and Technology
1445 – 1515	**Afternoon Tea**		

PROGRAM: THURSDAY 17 AUGUST

1515 – 1800	**Southern Ocean plankton: productivity, diversity, food-web dynamics, time-series & biogeochemistry / Processes and ecosystem response of the Southern Ocean**	**Taking the pulse on the Southern Ocean: an internationally coordinated, circumpolar, and year-round mission**	**Circumpolar Antarctic Ice Sheet-Ocean observations: towards an integrated view and improved climate models**
	Grand Ballroom 1	**Grand Ballroom 2**	**Grand Ballroom 3**
	Chairs: Sarat Chandra Tripathy, Ruth Eriksen, Toru Hirawake, Kazuhiro Yoshida, Kerrie Swadling, Luke Brokensha, Svenja Halfter	Chairs: Alexander Haumann, Stuart Corney, Petra Heil, Clive McMahon, Stefanie Arndt	Chairs: Andrew Meijers, Markus Janout, Felicity McCormack, Sue Cook, Pierre Dutrieux
1515 – 1530	**Subantarctic and Antarctic Peninsula Sediment Trap Water Soluble Organic Matter Characterization: Insights from Ultrahigh Resolution Mass Spectrometry** **Heather Forrer** EOAS Dept, Florida State University	3.15 – 3.23 **Introduction & Workshop Overview** 3.23 – 3.31 **The Polar POD expedition: a multi-year research voyage around the Southern Ocean** **Prof David Antoine** Curtin University	**Understanding the Southern Ocean through model-data synthesis** **Yoshihiro Nakayama** Hokkaido University
1530 – 1545	**Has the calving of the Mertz Glacier Tongue affected zooplankton community structure in a region of variable fast ice?** **Sylvie King** Institute for Marine and Antarctic Studies, University of Tasmania	3.31 – 3.39 **Bridging the gap for ice-ocean-ecosystem processes: Case Studies Integrated Observatory for the far East Antarctica-Ross Sea Region RSfEAR** **Dr Petra Heil** AAD & AAPP, Univerity of Tasmania 3.39 – 3.47 **The Norwegian Troll Observing Network marine observatories** **Tore Hattermann** Norwegian Polar Institute	**Ocean ridges impact the strength and location of deep warming and sea level changes** **Dr Kathryn Gunn** CSIRO Environment

1545 – 1600	**Using novel methods to detect ecological changes in species communities of the Southern Ocean.** **Yash Gimonkar** Institute for Marine and Antarctic Studies (IMAS, UTAS)	3.47 – 3.55 **Seasonal sea ice and snow properties as sensitive indicators for a changing Antarctic sea ice cover** **Dr Stefanie Arndt** Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung 3.55 – 4.03 **Closing the Southern Ocean heat and carbon budgets and understanding the underlying processes** **Alexander Haumann** Alfred Wegener Institute / Ludwig-Maximilian-University Munich	**Drivers of change in Antarctic Bottom Water and the deep overturning circulation** **Dr Steve Rintoul** CSIRO
1600 – 1615	**Long-term continuous plankton recorder data and joint species distribution models reveal changes in zooplankton communities in the Southern Ocean** **Dr Joel Williams** IMAS, University of Tasmania	4.03 – 4.11 **Observing water mass exchange across the Antarctic continental slope** **Dr Markus Janout** Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research 4.11 – 4.20 **Questions & Discussion**	**Abyssal ocean overturning slowdown and warming driven by Antarctic meltwater** **Prof Matthew England** University of New South Wales
1615 – 1630	**The Influence Of Feculence: Swimming Behaviour and Grazing Rate Changes Of Antarctic Krill (Euphausia Superba) In The Presence Of Guano** **Dr Nicole Hellessey** Georgia Institute of Technology	4.20 – 5.25 **Breakout Discussion**	**How to in SOOSmap** **Workshop**
1630 – 1645	**Long term monitoring of Southern Ocean plankton using the Continuous Plankton Recorder program** **Luke Brokensha** Institute for Marine and Antarctic Studies	4.20 – 5.25 **Breakout Discussion**	

PROGRAM: THURSDAY 17 AUGUST

1645 – 1700	**Up, down, and sideways: Antarctic krill (Euphausia superba) swimming behaviour in differing flow, light and chemical cue conditions** **Dr Nicole Hellessey** Georgia Institute of Technology	4.20 – 5.25 **Breakout Discussion**	
1700 – 1715	**Impacts of recent Antarctic Sea-Ice Extremes** **Dr Edward Doddridge** AAPP	4.20 – 5.25 **Breakout Discussion**	**Data Surgery** Are you using scientific data in your research and struggling to find the data you need? Are you unsure how to handle your data or need some advice on how to best share your data? A friendly team of data professionals from a number of data centres and data programmes with data management expertise will be happy to brainstorm a solution with you.
1715 – 1730	**Spatiotemporal variability of dissolved inorganic macronutrients along the northern Antarctic Peninsula** **Thiago Monteiro** FURG	5.25 – 5.43 **3-Minute summaries from breakouts**	
1730 – 1745	**Using a high-resolution model to understand changes in distribution of crabeater seals linked to climate change in the Southern Ocean** **Denisse Fierro Arcos** University of Tasmania	5.25 – 5.43 **3-Minute summaries from breakouts**	**Polardex/DueSouth** **Workshop**
1745 – 1800	**Observed Intrusion of Warm Modified Circumpolar Deep Water and Its Impact on Dense Shelf Water Formation** **Guijun Guo** First Institute of Oceanography, Ministry of Natural Resources	5.45 – 6.00 **Joint Discussion**	

0800 – 1300	**Registration Open** – Mezzanine Foyer
	Grand Ballroom
Gaps and next steps for the Southern Ocean Observing System Chair: Craig Stevens, NIWA/University of Auckland	
0830 – 1000	**Short Presentations from key observing initiatives** **NECKLACE** **INSTANT** **ASPeCT** **SORP** **AntClimnow** **SOCCOM** **BEPSII** **ICED** **MEASO** **Ant-ICON** **AniBOS** **IAATO** **Polar Citizen Science Collective** **European Polar Board** **EMODnet Physic**
1000 – 1030	**Morning Refreshments**
Gaps and next steps for the Southern Ocean Observing System Chair: Luciano Pezzi, National Institute for Space Research – INPE	
1030 – 1036	**ECR Perspective** **Kathy Gunn** CSIRO Environment Kathy's research aims to understand the drivers of ocean warming and freshening in the Southern Ocean. In this remote region, certain areas are experiencing accelerated trends, but it remains difficult to collect enough data to observe the ocean's true variability. 
1036 – 1042	**ECR Perspective** **Ethan Campbell** University of Washington Ethan Campbell is a Ph.D. candidate in physical oceanography at the University of Washington in Seattle. His dissertation research is focused on open-ocean polynyas, sea ice growth and melt, and snow processes in the Southern Ocean. Ethan has served as an APECS ECR representative on the SOOS Weddell Sea–Dronning Maud Land Regional Working Group since 2021. 
1042 – 1048	**ECR Perspective** **Alessandro Silvano** University of Southampton Alessandro is a NERC Independent Research Fellow at the University of Southampton (UK) studying the Southern Ocean and how it interacts with the climate system. Alessandro is particularly interested in understanding how these processes affect global sea level and ocean heat and carbon uptake. 

1048 – 1054

ECR Perspective

Minkyoung Kim

Kyungpook National University

Minkyoung is a passionate early-career chemical oceanographer, working at Kyungpook National University as an assistant professor (tenure-track). By using the radiocarbon and lipid biomarkers, Minkyoung aims to obtain insights on carbon and related biogeochemical cycling in global oceans.

1054 – 1100

ECR Perspective

Svenja Halfter

NIWA

Svenja Halfter is a zooplankton ecologist and biogeochemist based at NIWA in Wellington, New Zealand. Their research focuses on understanding the zooplankton dynamics and the impact of climate change on lower trophic levels in the Southern Ocean, mainly in the Indian and Pacific sectors.

1100 – 1200

Irene Schloss

Instituto Antártico Argentino, Argentina

Dr. Irene Schloss is a biological oceanographer at Austral Center for Scientific Research from the National Council of Scientific Research (CONICET) in Ushuaia Argentina. She is also affiliated to Argentinean Antarctic Institute and the Tierra del Fuego National University.

1200 – 1230

Symposium Closing

Dr Alyce Hancock, Executive Officer SOOS

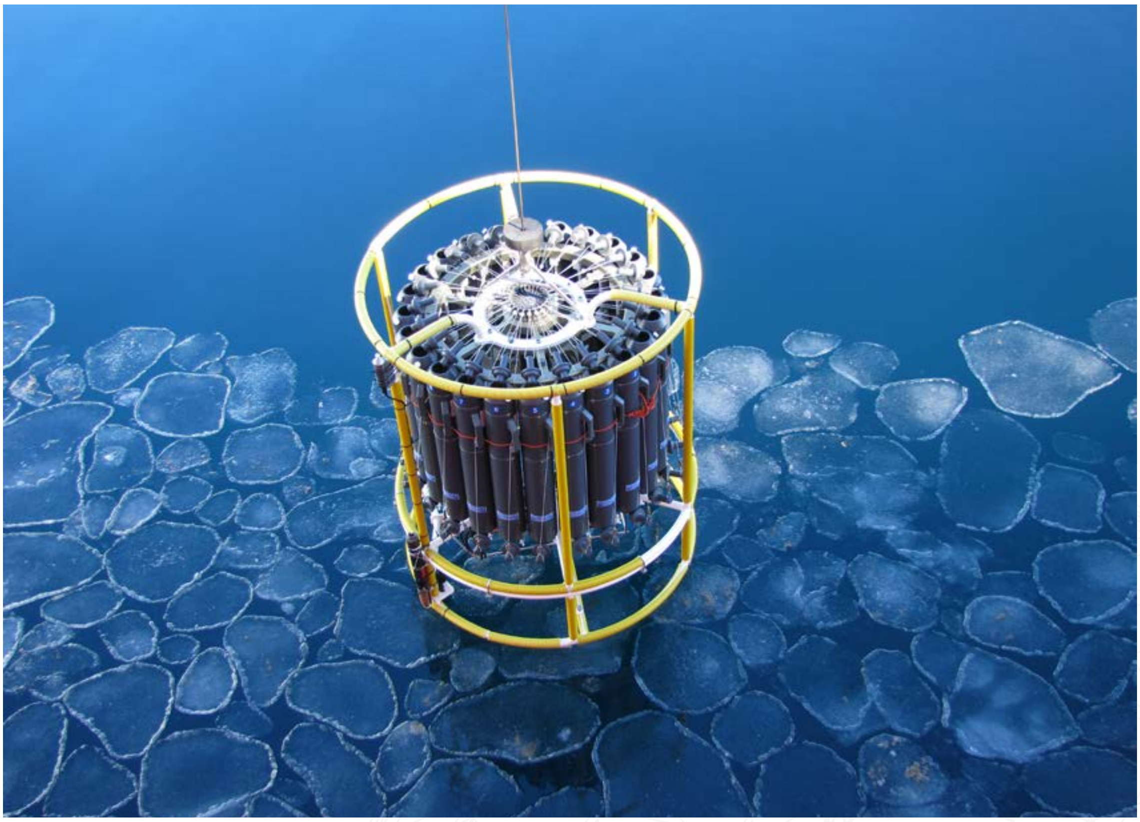


Photo Credit: Seb Swart

ACEAS

Australian Centre for Excellence in Antarctic Science

A Special Research Initative of the Australian Research Council

The Australian Research Council (ARC) Australian Centre for Excellence in Antarctic Science (ACEAS) is a collaboration between Australian universities, government agencies and international research institutions.

Our objective is to help communities prepare for climate risks emerging from East Antarctica and the Southern Ocean. We will do this by integrating knowledge of the region's ocean, atmosphere, cryosphere, and ecosystems.

Our research questions

How can we better understand shifts in carbon dioxide, heat, and moisture transport in the Antarctic and Southern Ocean to improve projections of future climate and sea level changes?

What are the links between atmosphere, ocean, cryosphere, and their effects on East Antarctica's open water and under-ice biogeochemistry and ecology under past, present, and future conditions?

What is the risk to our communities of ice mass loss from key subglacial basins over the next decades to centuries, and what are the consequences for the East Antarctic ocean and ecosystem?

Our people

38 Chief Investigators

37 Postdoctoral Investigators

24 PhD Candidates

Our structure & stakeholders

The Centre is committed to delivering new knowledge of East Antarctica and the adjacent Southern Ocean, connecting the researchers with the community, governments, industry, and academia.

Our Program

ACEAS' research program is funded by $25 million of ARC and Australian university funds. The program commenced in late 2021 and is funded to run until 2025.

Australian Government
Australian Research Council

The Australian Centre for Excellence in Antarctic Science is a Special Research Initiative funded by the Australian Research Council

www.antarctic.org.au

ANGUS ALDIS

Navigating polar science is tricky, especially for researchers with disabilities. Issues persist that disqualify researchers with disabilities from pursuing their dreams. To address this, Accessibility in Polar Research (APR/@accesspolar) was founded during the pandemic by a small group of researchers with disabilities. Through appearances at conferences, designed workshops and made resources APR grew rapidly and garnered an international platform to carry out its initiatives. One such initiative is the 'Accessibility 2023 Questionnaire', designed to evaluate how the polar field restricts researchers with disabilities. Through collating this information APR is in the process of creating free and open resources for institutions, fieldwork organisers and employers to ensure inclusivity is practiced.

KIMBERLY AIKEN

Kimberly is a PhD student at the University of Tasmania, Australia, Institute for Marine and Antarctic Studies, undertaking a research project focused on building more diverse, equitable, and inclusive extreme and remote workforces with lessons from Antarctica, Outer Space and Underground Mining using intersectionality to examine overlapping identities such as race and gender to promote recruitment and retention of historically underrepresented groups. Kimberly has a master's in international environmental policy, worked on Arctic Governance with the Alfred Wegener Institute German Arctic Office, Arctic plastic pollution in Norway with GRID-Arendal and Antarctic and Southern Ocean environmental protection with the Antarctic and Southern Ocean Coalition. Kimberly has contributed to several outreach and advocacy platforms such as EU4Oceans and the Historians for Future podcasts, magazine interviews, and created a story map on Securing the Next 30 Years of Antarctic Protection highlighting the significance of protecting the polar regions. Kimberly co-leads the Diversity and Inclusion Community Practice Group with the Interagency Arctic Research Policy Committee (IARPC) and published commentary articles with the Arctic Institute and the Cardiff University Arctic Scholarship & Stories to facilitate discussion on diversity and inclusion in Arctic policy and polar science. Kimberly was a 2019 Center for the Blue Economy fellow at the Middlebury Institute of International Studies and a Student Forum scholarship recipient at the 2020 Arctic Frontiers Conference in Norway. Kimberly is a polar expert with the Oregon State University Polar STEAM Program, a member of the Antarctic Women's Network, Women in Polar Science, Women in Arctic and Antarctica, the SCAR Equity, Diversity, and Inclusion Action Group, an Executive Committee member of APECS Oceania, and a member of the Centre for Marine Socioecology. Kimberly enjoys exposure to different cultures and food, and a wide range of outdoor activities when she is not working for Antarctica or participating in Arctic engagements.

RENUKA BADHE

Dr Renuka Badhe serves as the Executive Secretary of the European Polar Board since 2015. As a knowledge broker with a background in oceanography, economics and public policy, she has longstanding expertise working with a wide range of international organisations and projects at the interface of science, policy and/or strategy development or overlaps thereof. She is a passionate advocate for diversity in polar research and has founded the Women in Polar Science network to highlight and promote women working in all aspects of polar research, particularly as an outspoken advocate for members of underrepresented communities. She has mentored early career researchers globally, and was awarded the 2017 APECS International Mentorship Award.

ETHAN CAMPBELL

Ethan Campbell is a Ph.D. candidate in physical oceanography at the University of Washington in Seattle. His dissertation research is focused on open-ocean polynyas, sea ice growth and melt, and snow processes in the Southern Ocean. Ethan has served as an APECS ECR representative on the SOOS Weddell Sea–Dronning Maud Land Regional Working Group since 2021. His interests include promoting reproducible and open science, advancing evidence-based teaching practices, fostering diverse and inclusive spaces within institutions, and engaging in local transportation-related activism and advocacy.

ALISON CLAUSEN

Alison Clausen is the Deputy Global Coordinator of the UN Decade of Ocean Science for Sustainable Development at IOC-UNESCO. She joined IOC as a programme specialist in 2019 with over twenty-five years' professional experience in program and project development and management in the areas of marine conservation, marine policy, and climate change adaptation. Before joining IOC she was based in Madagascar, where she worked throughout the Western Indian Ocean region for the World Bank and most recently as the Regional Director for the Madagascar and Western Indian Ocean program of the Wildlife Conservation Society. Prior to that she lived in Vietnam where she worked through South East Asia for a range of development banks, UN agencies and NGO partners.

STUART CORNEY

Dr Stuart Corney is a senior lecturer and Associate Head Learning and Teaching at the Institute for Marine and Antarctic Studies at the University of Tasmania. Stuart's research focuses on the interface between the physical environment and ecosystem dynamics. He is particularly interested in understanding how climate variability and anthropogenic climate change influences individual and population success of Southern Ocean marine species. Working in a multidisciplinary field necessarily involves collaboration and Stuart has built a diverse group of collaborators with a range of specialisations from ocean modellers through to ecologists and field biologists representing many organisations around the world.

Stuart is currently co-chair of the IMBeR regional program Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED), is part of the leadership team coordinating the Southern Ocean Collaborative Centre for the UN Decade for Ocean Sciences and is the Southern Ocean representative on the Predicted Ocean collaborative centre for the UN Decade.

Stuart's current focus is developing an earth system model that includes krill life history and ecosystem dynamics.

KAREN EVANS

Dr Evans is a principal research scientist and team leader with CSIRO Oceans and Atmosphere based in Hobart, Tasmania. She leads and contributes to research focused on progressing scientific understanding and developing options to improve marine resource management, particularly in relation to national and international fisheries and threatened, endangered and protected species. Her projects deliver strategic research to national agencies, regional programmes in the Pacific and Indian Oceans and international agencies, including the United Nations. She co-chairs a panel of experts developing a global set of measurable indicators of ocean biology and ecology for the Global Ocean Observing System and is a member of the group of experts guiding the United Nations regular World Ocean Assessment process.

KATHY GUNN

Kathy's research aims to understand the drivers of ocean warming and freshening in the Southern Ocean. In this remote region, certain areas are experiencing accelerated trends, but it remains difficult to collect enough data to observe the ocean's true variability. To further understand what is driving those changes and what we can expect in the future, Kathy uses a combination of physical observations (e.g., temperature and salinity shipboard measurements), acoustic observations (e.g., seismic reflection surveys), and model output.

THE HON. SIR GUY GREEN, AC, KBE, CVO

Born in Launceston in 1937, Guy Green studied Law at the University of Tasmania and after being admitted to the bar in 1960, practised in Launceston. Intelligent, congenial, conciliatory and highly respected, an enthusiastic promoter of Tasmania, Guy Green was an obvious candidate for high office. Chief justice from 1973 to 1995, he was knighted in 1982 and served as Chancellor of the University of Tasmania (1985 – 95), Governor of Tasmania (1995 – 2003), and Administrator of Australia on several occasions. Green has chaired many bodies, ranging from St John Ambulance to Ten Days on the Island and the Tasmanian Museum and Art Gallery; an excellent speaker, he has delivered many orations and speeches; a thoughtful writer, he has written many articles, chapters and forewords.

Originating from Launceston, but having lived for many years in Hobart and knowing both communities, Green was well qualified to act as Chancellor during the difficult period when the southern-based University of Tasmania amalgamated with the northern Tasmanian State Institute of Technology. He was closely involved with selecting the new Vice-Chancellor and with the amalgamation process, assisting to draft the enabling legislation which 'invented' the new University.

Green felt that many matters were more properly the province of the Vice-Chancellor, but was conscious of the importance of the Chancellor's advisory and supporting role. He was particularly concerned with maintaining the significance of graduation ceremonies, and was much involved in the University's centenary celebrations. His leadership assisted the University enormously during these difficult years of change.

SVENJA HALFTER

Svenja Halfter is a zooplankton ecologist and biogeochemist based at NIWA in Wellington, New Zealand. Their research focuses on understanding the zooplankton dynamics and the impact of climate change on lower trophic levels in the Southern Ocean, mainly in the Indian and Pacific sectors. During their PhD, Svenja worked on zooplankton-mediated carbon flux in the subantarctic Southern Ocean and was part of MEASO (Marine Ecosystem Assessment of the Southern Ocean). Svenja is involved in the SOOS RWG for the Indian Sector since 2020, first as an APECS ECR representative and now as a full member. Outside of SOOS, Svenja is also part of the SCAR Expert Group on Antarctic Biodiversity Informatics, the SCAR scientific research program Ant-ICON, and the Ocean Decade program JETZON (Joint Exploration of the Twilight Zone Ocean Network).

INDI HODGSON-JOHNSTON

Indi is the ACEAS Chief Operating Officer and is an Adjunct Senior Researcher in Antarctic and oceans law and policy at the Institute for Marine and Antarctic Studies at the University of Tasmania. She also works as a rapporteur at the Antarctic Treaty Consultative Meetings, and is Senior Deputy Chair of the Tasmanian Polar Network Executive. Indi was formerly Deputy Director of Australia's Integrated Marine Observing System. She has held academic and legal advisory roles and worked at sea for many years. She holds degrees in law, policy, and Antarctic studies, a PhD in law, and is a Barrister and Solicitor of the Supreme Court of Tasmania.

EILEEN HOFMANN

Eileen Hofmann is Professor and Eminent Scholar in the Department of Ocean and Earth Sciences and a member of the Center for Coastal Physical Oceanography at Old Dominion University. Her research on understanding physical-biological interactions in marine ecosystems was recognized by her election as Fellow of the American Geophysical Union. Her research has focused on a range of marine environments, most recently the continental shelf region of the Ross Sea and the Middle Atlantic Bight of the east coast of the United States. She contributed to the initial 2010 SOOS Science Plan and she presently serves as Co-Chair of SOOS. She contributed to development of the Southern Ocean Action Plan that provides a vision for the Southern Ocean community that aligns with the goals of the UN Decade of Ocean Science. Prior to SOOS, Professor Hofmann served as Chair of the Integrated Marine Biosphere Research Project and as Chair of the Southern Ocean Global Ocean Ecosystem Dynamics program. Throughout her career she had been committed to education of the next generation of marine scientists.

DANI JONES

Dr Dani Jones is a Physical Oceanographer and a UKRI Future Leaders Fellow at the British Antarctic Survey. Their research focuses on using numerical modeling (including adjoint modeling) and unsupervised classification to gain insight into ocean structure and dynamics. Recently, their work has focused on adjoint sensitivity experiments and observing system design, with a geographic focus on the Weddell Gyre.

MINKYOUNG KIM

Minkyoung is a passionate early-career chemical oceanographer, working at Kyungpook National University as an assistant professor (tenure-track). By using the radiocarbon and lipid biomarkers, Minkyoung aims to obtain insights on carbon and related biogeochemical cycling in global oceans. It is MInkyoung's honor to participate in the SOOS ECR Perspective Plenary!

NOAH LAWRENCE-SLAVAS

Noah Lawrence-Slavas is the principle mechanical engineer for the NOAA's Pacific Marine Environmental Laboratory where he leads diverse engineering teams, collaborating with principle scientific investigators, to innovate and develop new tools for scientific research. Noah is passionate about applied research and development, and he thoroughly enjoys the process of turning an idea into an operational product. Over a 23-year career, Noah has gained extensive experience in ocean research and development, including the design of complex ocean instrumentation, buoys, and global observation arrays. He is well versed in the at-sea recovery and deployment of moorings and oceanographic instrumentation, as well as the unique challenges faced by ocean scientists.

Noah is particularly interested in how to rapidly develop, and scale, our ability to observe the environment by leveraging partnerships and holistic instrument design to deliver high quality, well described, and useful data directly to scientists. His current research focuses on the development of ocean carbon sensors, and expanding the spatial and temporal coverage of ocean observations through the use of robotic vehicles and small low-cost platforms. He has led the MAPCO2™, MADIC, and ASVCO2™ ocean carbon instruments' engineering development efforts, and the design, integration, and validation of instrumentation into the saildrone Uncrewed Surface Vehicle (USV).

Noah has been honored with the Ron Brown Excellence in Innovation award (1), the U.S. Department of Commerce Gold(3), Silver(1) and Bronze (1) Medals, a NOAA Ocean and Atmospheric Research (OAR) employee of year award for his engineering contributions to ocean research, a Froehlich invitational fellowship, and a NOAA Technology Transfer Award for transitioning the MAPCO2 system from government research to industry.

ANDREW MEIJERS

Andrew Meijers is a physical oceanographer at the British Antarctic Survey. He specialises in the large-scale ocean circulation and change around Antarctica, using both observations and climate models. Hailing from Tasmania, he undertook his PhD at the University of Tasmania and spent several years at the CSIRO Atmospheres and Oceans, before moving to BAS in 2012. He has gained extensive field experience on the Southern Ocean and has led three expeditions as chief scientist. He presently acts as the Deputy Science Lead of the BAS Polar Oceans programme, and as the Scientific Coordinator of the large Horizon Europe OCEAN:ICE programme; seeking to understand the role of ocean-ice sheet coupling and feedbacks in our future climate. Prior to this he acted as the Principal Investigator of the UK ORCHESTRA programme, and its follow-on ENCORE, which sought to understand the Southern Ocean's role in storing, subducting and exporting heat and carbon.

STEPHEN R RINTOUL

Dr Stephen R. Rintoul AO AAM FAA is a physical oceanographer and climate scientist at CSIRO Environment and the Australian Antarctic Program Partnership in Hobart. His research is focused on the role of the ocean in the climate system. He has a particular fascination for the Southern Ocean, where his work has led to a deeper appreciation of the influence of the region on global climate, biogeochemical cycles, and the vulnerability of Antarctic ice shelves. He uses observations from ships, floats, moorings, seals and satellites to investigate the dynamics of the Antarctic Circumpolar Current, the overturning circulation, and ocean – ice shelf interaction. He has led 15 expeditions to the Southern Ocean. Dr Rintoul has coordinated major international Southern Ocean climate research programs, including the Southern Ocean component of WOCE, CLIVAR and the IPY. He organised a meeting in Hobart in 2006 that seeded the idea of a Southern Ocean Observing System and led the writing of the first SOOS science plan in 2010. His scientific achievements have been recognised by many national and international awards, including the Martha T Muse Prize, the Australian Antarctic Medal, and election as a Fellow of the Australian Academy of Science.

IRENE SCHLOSS

Dr. Irene Schloss is a biological oceanographer at Austral Center for Scientific Research from the National Council of Scientific Research (CONICET) in Ushuaia Argentina. She is also affiliated to Argentinean Antarctic Institute and the Tierra del Fuego National University. She played a leading role in many international research projects, relating climate change to CO_2 fluxes between the atmosphere and the ocean, the effects of UVB radiation and the role of the marine plankton. In the last 25 years, she developed a wide expertise in the dynamics of polar and sub-polar marine plankton, temporal and spatial variations of plankton communities and the response of physicochemical variables to global climate change from field data, experimental work and modelling. Dr. Schloss is committed to promoting international scientific co-operation, particularly with regard to research in Polar Regions, and is currently Vice-Chair of SOOS.

ALESSANDRO SILVANO

Alessandro is a NERC Independent Research Fellow at the University of Southampton (UK) studying the Southern Ocean and how it interacts with the climate system. Alessandro is particularly interested in understanding how these processes affect global sea level and ocean heat and carbon uptake.

OSCAR SCHOFIELD

Oscar M.E. Schofield, is a distinguished professor and the chair of the Department of Marine and Coastal Sciences at Rutgers, The State University of New Jersey. He is interested in how plankton dynamics structure marine food webs and feedback on the ocean's biogeochemistry. His research focus has combined genetics and biochemistry with the development of new ocean observing technologies (satellites, radars, and autonomous underwater vehicles). He is co-director and co-founder of the Coastal Ocean Observation Laboratory, which has been awarded and managed numerous competitive awards from NOAA, Office of Naval Research, Department of Homeland Security,NASA and the National Science Foundation. Dr. Schofield's research efforts have focused on polar and temperate waters with extensive efforts in the Southern Ocean, with ongoing research along the West Antarctic Peninsula and the Ross and Amundsen Seas. He completed his BA and PhD in Biology at the University of California, Santa Barbara.

ALEX THORNTON

Alex Thornton is the founder of Pride in Polar Research (PiPR), a global, volunteer-run group that supports, uplifts, and creates community for those with minority LGBTQIA+ identities in polar science. As an openly queer, intersex, and disabled marine scientist and educator from an international, multicultural family, he is deeply committed to creating access and equity for underrepresented communities in STEM, particularly for those at the intersectionality of marginalization. Alex emphasizes the need to actively create and hold space for diverse minds in order to reduce harm as opposed to expecting minority populations to conform to life in chronically inaccessible institutions.

Alex currently works as the Summer Course Coordinator & Lecturer for the MAS MBC and PIER programs at UCSD's Scripps Institution of Oceanography. Alex is an alum of the MAS MBC class of 2014 and spent the last decade in Alaska, where he received a graduate certificate in Science Teaching & Outreach from the University of Alaska Fairbanks. He has since shared his passion for marine conservation and SciComm with professionals, grad researchers, undergrads, and K-12 students around the world.

Alex has a life-long fascination with penguins and is especially interested in how life thrives in extreme environments—from the poles to the deep sea. He has conducted interdisciplinary research on marine mammal and seabird biology, fisheries management, animal welfare, environmental tourism, conservation ethics, and ocean law. In this work and beyond, Alex leans on his diverse professional experiences and strives to collaboratively and ethically link findings from western science with Indigenous knowledge.

You can reach Alex with any questions or collaboration ideas at alex@prideinpolarresearch.com.

ANTON VAN DE PUTTE

Dr Anton Van de Putte is a marine biologist and open science advocate who obtained a PhD from the KULeuven working on the ecology and evolution of Antarctic fish.

During his PhD he developed a strong interest in the Antarctic treaty system and it's spirit of cooperation. In particular the idea that scientific observations and results from Antarctica shall be exchanged and made freely available.

In 2012 he became the coordinator of the SCAR Antarctic Biodiversity Portal (formerly SCAR-MarBIN) at the Royal Belgian Institute of Natural Sciences. As the regional node manager of the Ocean Biodiversity Information System (OBIS) and the Global Biodiversity information Facility (GBIF) he is passionate about making Antarctic and Southern Ocean Biodiversity data publicly available. He is part of the SCAR Standing Committee on Antarctic Data Management and the SOOS Data Management Sub Committee.

Since 2016 he is the Belgian scientific representative to Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) where he is particularly interned in ecosystem based management, the development of Marine Protected areas and the possible effect of climate change.

Since 2020 he is also affiliated with the Marine Biology lab at the University Libre de Bruxelles. In this position he is keen on applying open science to better understand the distribution of Antarctic and Southern Ocean organisms and develop open science tools that translate open data into data products that can support policy decision making.

VITO VITALE

Vito Vitale is Research Director at the CNR Institute of Polar Sciences (ISP) in Bologna. He is an expert of radiative transfer processes into the atmosphere, with research focus on radiation budget and role that atmospheric composition and surface characteristics play in modulating Shortwave (SW) and Longwave (LW) radiation components, determining their seasonal and inter-annual variability. He have been involved in polar research and management since 1986, both in Antarctica and in the Arctic. He leads the Climate Change Tower Integrated Project (CCT-IP, www.isac.cnr.it/~radiclim/CCTower) a large multidisciplinary project at CNR Arctic Station Dirigibile Italia, aiming to investigate arctic ABL energy budget, and role played by different processes involving air, aerosols, clouds, snow, ice and land (permafrost and vegetation) using well integrated multidisciplinary platforms. During his long activity in polar regions, he has promoted the improvement of observation technology for harsh environments, developing also custom instrumentation. With respect this last topic, current interest is devoted to increase the capability to perform continuous atmospheric observations over ocean, in particular those related to radiation and aerosols. In relation to data: (i) in the frame of National Antarctic Programme (PNRA) and Arctic Research Programme (PRA) he is coordinating decelopment and implementation of Italian Polar Repositories: National Antarctic Data Centre (NADC) and Italian Arctic Data Centre (IADC); (ii) has the responsability to coordinate CNR contribution to SIOS (Svalbard Integrated Observing System) distributed DMS through IADC; (iii) leaded development of the ARICE EU Project Data Manangement tools.

Photo Credit: Alyce Hancock

SYMPOSIUM APP

The Symposium App has a variety of applications to enhance your experience and engagement at the symposium.

Please refer to the email sent to you prior to the symposium which included detailed user guidelines for the Symposium App. For most attendees, you are able to download and install the Symposium App from your Android or Apple App Stores.

1. Search for The Event App by EventsAIR in your Android Play or Apple Store.
2. Install The Event App by EventsAIR.
3. The first time* you open the app, you will need to enter this event code: **SOOS2023**
4. Your app opens, and you will need to enter your email address and your four-digit APP Pin which was sent to you via email prior to the symposium or can be found on the bottom of your name badge.

*If you have previously used The Event App by EventsAIR at another event, you will need to log out to open the current version of the app Via the app, you will be able to:

- View the interactive program
- Connect and exchange contact details with other attendees via the Meeting Hub
- View Speaker Profiles
- Post your experiences and interact with other delegates via the EventStream.

If you need help with any aspect of the Symposium App please see staff at the Registration Desk.

The Live Q&A component of the Symposium will take place on **Slido**. You can submit questions via the program (anonymously or with your name) .

Slido vent "key" = #SOOSSymposium2023

REGISTRATION DESK

The Registration Desk, located in the Mezzanine Level Foyer, will be open for the duration of the symposium. Leishman Associates staff will be available to assist delegates at the following times:

Monday 14 August	0730 - 1730
Tuesday 15 August	0800 - 1730
Wednesday 16 August	0800 - 1730
Thursday 17 August	0900 - 1800
Friday 18 August	0800 - 1300

SYMPOSIUM NAME BADGES

On registration all delegates and exhibitors will be provided with a name badge, please wear this at all times to identify yourself as an attendee at the symposium. Please treat with care. We have chosen not to use the more durable plastic pockets in our efforts to reduce our symposium environmental footprint.

The icons printed on the bottom of your name badge refer to the following:

(dinner icon)	Indicates that you have booked the Symposium Dinner
(phone icon)	Is your unique PIN used to log in to the Symposium App
(WiFi icon)	Indicates Symposium WiFi
(lock icon)	Indicates WiFi password

WIFI COMPLIMENTARY

WiFi will be available onsite for the duration of the symposium. How to connect to the symposium WiFi:

1. Find the WiFi connection – **SOOS**
2. In the login field enter username: **SOOS2023** (case sensitive)
3. Once entered – please press 'log in' and you will be connected.

If you have trouble connecting please see staff at the Registration Desk.

Note: Please be aware that the complimentary WiFi is for the use of the symposium app, web browsing and checking web-based email. It is not designed for accessing VPN's or downloading large files. The Venue, the Symposium Managers and the Symposium Organising Committee accept no responsibility for any viruses or security breaches encountered whilst using their internet service. The internet is not to be used to view or download any illicit material, including movies, music etc.

SYMPOSIUM SESSIONS

The symposium plenary sessions will be held in The Grand Ballroom with the concurrent sessions running in Grand Ballroom 1, Grand Ballroom 2 & Grand Ballroom 3.

Delegates should arrive promptly to their preferred sessions to avoid disturbing the speaker and to assist sessions to run on time.

SPEAKERS' PREPARATION ROOM

The Speakers' Preparation Room is located on the mezzanine level. Speakers are asked to report to the Speakers' Preparation Room to load their PowerPoint presentations onto the symposium network AT LEAST two hours before the scheduled presentation time; this may mean the day before.

Computer and audio-visual equipment will be available for speakers wishing to review or change their presentations with the audio-visual technician.

The Speakers' Preparation Room will be open at the same time as the Registration Desk.

PHOTOGRAPHS, VIDEOS, AND RECORDING OF SESSIONS

Delegates are not permitted to use any type of camera or recording device at any of the sessions unless written permission has been obtained from the relevant speaker.

PRESENTATIONS

All session PowerPoint presentations (converted to PDF format), will be posted to the SOOS Symposium website on a password-protected page after the event.

If you do not wish your presentation to be made available on the website, please notify the staff in the Speakers' Preparation Room.

MOBILE PHONES

As a courtesy to other speakers and delegates, please ensure that all mobile phones are in silent mode during sessions and social functions.

DATA HELPDESK – WEDNESDAY

Are you using scientific data in your research and struggling to find the data you need? Are you unsure how to handle your data or need some advice on how to best share your data?

Come to our Data Helpdesk stand or Data Surgery session!

A friendly team of data professionals from a number of data centres and data programmes with data management expertise will be happy to brainstorm a solution with you.

SPECIAL DIETS

All catering venues have been advised of any special diet preferences you have indicated on your registration form.

Please identify yourself to venue staff as they come to serve you and they will be pleased to provide you with all preordered food.

For day catering, there may be a specific dietary buffet, please check with catering or symposium staff.

TRADE EXHIBITION AREA

The Trade Exhibition Area will be situated on the mezzanine level on Wednesday and Thursday only, from the start of the morning refreshment break till the end of the afternoon refreshment break each day.

CAR PARKING

The Hotel Grand Chancellor Hobart offers parking for in-house accommodation guests for just $15 a night for self-parking, or $26 for our valet service.

- Ticketed hourly rates start from $3 per hour or $16
- Early bird rate available - Entry before 9am | exit before 6pm

For more information click here.

PUBLIC TRANSPORT TO HOTEL GRAND CHANCELLOR HOBART

The hotel is located at 1 Davey Street, Hobart, 18kms away from Hobart International Airport (HBA) it's a 20-minute drive via the Tasman Highway (A3).

Coming from the Airport - options include driving, taking a cab or Uber, or the SkyBus which operates daily, you will find the pick-up and drop-off spot right outside the hotel (timetables and more information click here), or transfer in style with Corporate Cars (find their website here)

ACCOMMODATION

If you have any queries relating to your accommodation booking, please first see staff at the hotel.

CERTIFICATE OF ATTENDANCE

After the symposium, all delegates will be issued with a certificate via email.

Code of Conduct for the SOOS Symposium 2023

The Southern Ocean Observing System (SOOS) aims to convene a Symposium that is welcoming, respectful, inclusive, and collaborative, and is confident that the community is committed to this outcome. We recognize that the accessibility of such a Symposium is partly determined by how safe it is to attend, with safety tied closely to participants' race, gender, gender identity, sexual orientation, religion, ability, and other factors. This Code of Conduct has been developed to help create an inclusive and productive environment that will foster positive discussion, as well as to encourage participants to consider the viewpoints of others, including those who might otherwise be overshadowed by more mainstream voices and/or opinions.

The SOOS Symposium is being hosted by the University of Tasmania (UTAS) and as such, is also governed by UTAS's Behaviour Policy (sections 1 [Behaviour] and 2 [Support for community members] only).

Expected behaviour

- Treat everyone with respect and consideration, including:
  - Communicating openly and thoughtfully with others.
  - Being considerate of the multitude of views and opinions that are different from yours.
  - Being mindful in your critique of ideas.
- Be considerate of your physical surroundings and of your fellow participants.
- Respect the rules and policies of the meeting venue, hotels, online platform, or any other venue. At the symposium:
  - Provide your true professional identity, affiliation, and, where appropriate, contact information, at registration and during attendance and participatory sessions, as required.
  - The SOOS Symposium encourages the presentation of unpublished research; you are expected to respect the confidentiality of all presentation materials and ideas unless you obtain specific permission from all the authors concerned.

Anyone not meeting expected, collaborative, respectful behaviour will be reported to their university, institute and or local authorities, depending on the specifics of the unwelcomed disruptive behaviour, and can be immediately removed from the meeting and may be banned from future meetings.

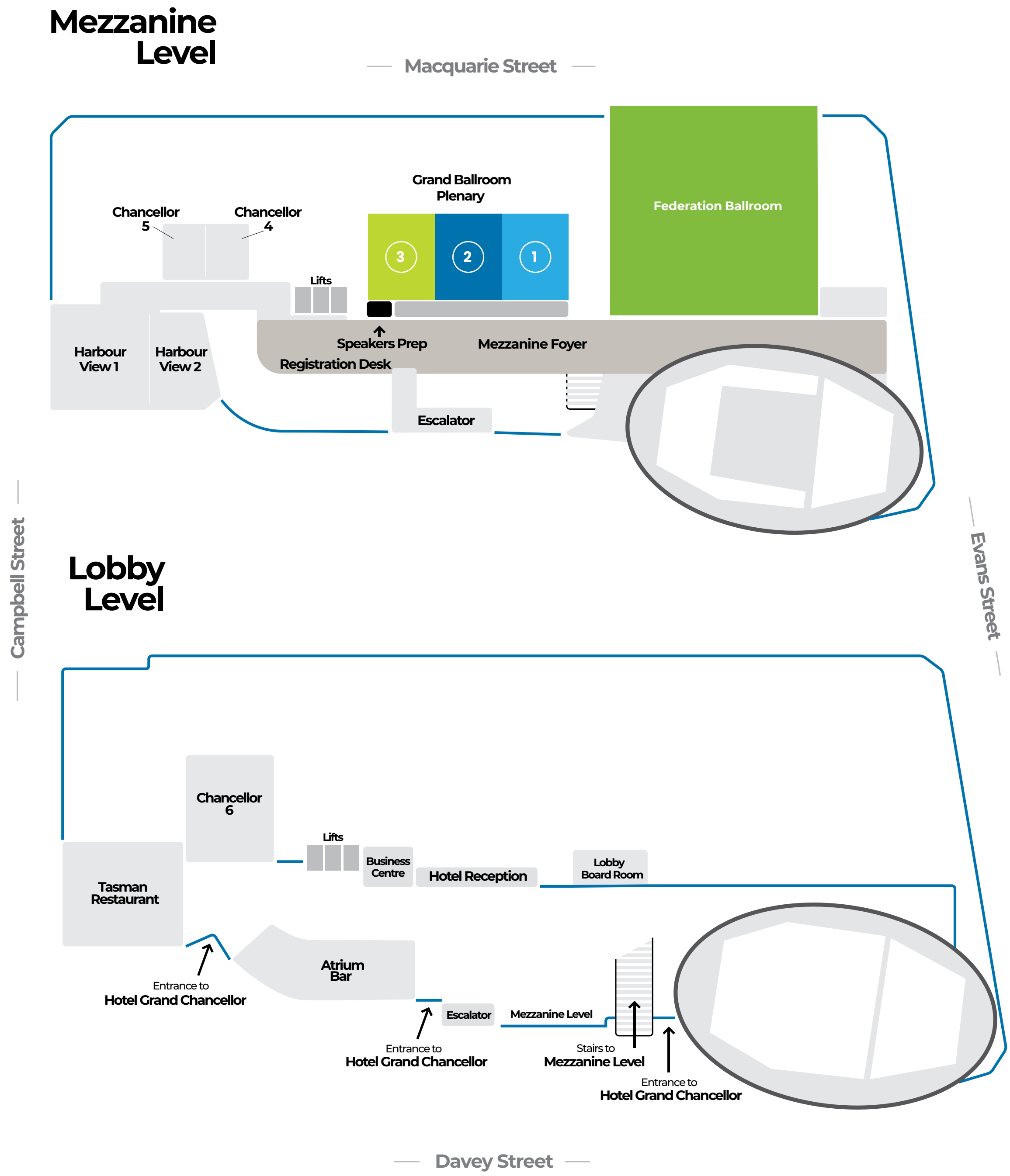
Examples of unacceptable behaviour

- Promoting or participating in harassment, bullying, discrimination, or intimidation on-site, online, and/or on social media.
- Physical, verbal, or written forms of abuse including, but not limited to, verbal comments related to gender and gender identity, sexual orientation, disability, physical appearance, body size, race, religion, national origin or culture, inappropriate use of nudity and/or sexual images in public spaces or in presentations, and attacks on ideas (versus respectful, disagreeing dialogue). This includes any attendee, speaker, volunteer, staff member, service provider, or other guest.
- Threatening or stalking in-person or online.
- Disruption of presentations/sessions or disallowing participation by others.
- Use of social or mainstream media to target individual actions of participants in a way that could harm their privacy or professional status or open them to slander or libel.
- Knowingly violating copyright or copying presenter information without obtaining permission.
- Criminal offences.
- Failure to follow Symposium protocols.
- Consequences and reporting of unacceptable behaviour
- By registering for the SOOS Symposium, participants acknowledge and agree to abide by the meeting Code of Conduct.
- Anyone requested to stop unacceptable behaviour is expected to comply immediately.
- Anyone violating the Code of Conduct may be removed from the Symposium without warning and potentially without refund. SOOS reserves the right to prohibit attendance at any future meeting if it is felt the future safety of delegates would be at risk.
- For participants who wish to lodge a complaint of harassment or other inappropriate behaviour, two Safety Officers will be available and readily identifiable. The Safety Officers have received training in how to deal with issues that may arise and will work closely with the appropriate teams at the University of Tasmania (UTAS) that will be on stand-by for the week of the Symposium[2]. All discussions will be managed in a secure and private space, and any documentation arising from reported incidents will be stored in a secure OneDriver folder. The Safety Officer will discuss the incident with the participant lodging the inquiry or complaint and will determine the steps that may need to be taken to make the participant feel safe. These interventions will be supported by the appropriate UTAS teams if necessary. Complaints and/or inquiries may additionally/alternately be communicated to info@soos.aq.
- If you experience or witness behaviour that constitutes an immediate or serious threat to public safety, please contact the conference organizers/Safety Officers and ask for security, and call the Australian Emergencies Services via Triple Zero, 000. Any other incidents or suspected incidents can be reported to the Safety Officers.

[1]This Code of Conduct has been adapted from that of the American Geophysical Union and the International Marine Conservation Congress [Favaro, B. et al. (2016) Your science conference should have a code of conduct. Frontiers in Marine Science 3:103, 10.3389/fmars.2016.00103].

[2]The support/assistance from UTAS is available for the week of the Symposium only. Beyond this time, Symposium staff will escalate any issues raised to the home institutions/agencies of the parties involved.

HOTEL GRAND CHANCELLOR



Grand Ballroom: Plenary

- **Grand Ballroom 1: Breakout 1**
- **Grand Ballroom 2: Breakout 2**
- **Grand Ballroom 3: Breakout 3**
- **Speakers Prep: Speakers Prep**
- **Mezzanine Foyer: Registration, Exhibition & Catering**
- **Federation Ballroom: Poster Session/Catering – Tuesday Only**

SYMPOSIUM DINNER

Date: Wednesday 16 August, 1830

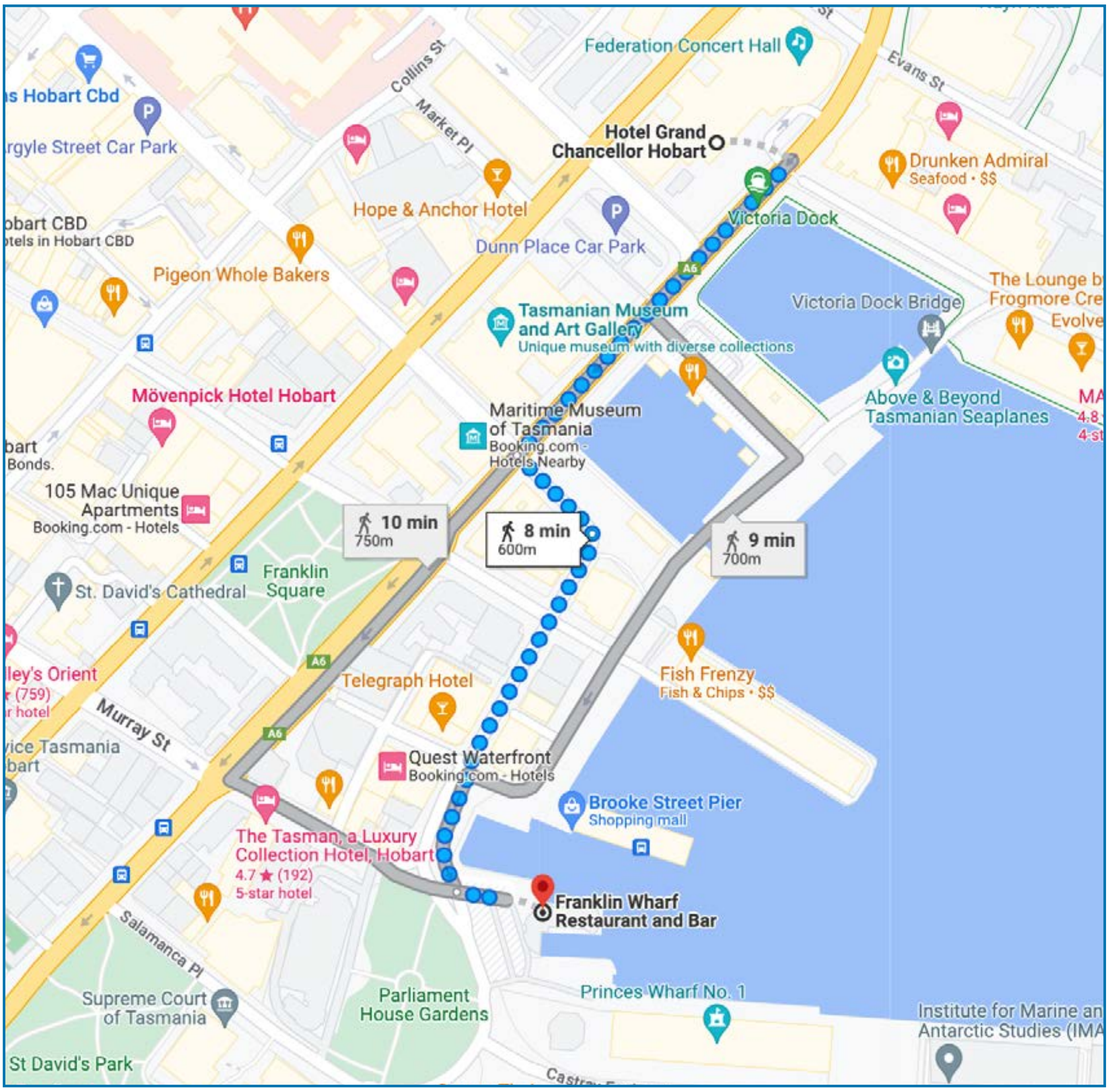
Location: Franklin Wharf Function Centre

This will be a night for networking and savouring the fine Tasmanian produce the state has become known for. Franklin Wharf is a short 5 minute scenic walk from the Symposium Venue along Hobart's waterfront, a working port and home to the Antarctic icebreaker, Nuyina. After the Symposium dinner, you can continue enjoying Hobart's hospitality at the adjacent restaurant/bar precinct Salamanca.

Dress code: Smart Casual

The Symposium Dinner fee is not included in the cost of registration. Tickets can be purchased at $95.00 per person or $85.00 per person for a student/developing country registration.

No beverages included; cash bar available.



THANK YOU

OUR SPONSORS

- AAPP – Australian Antarctic Program Partnership
- ACEAS – Australian Centre for Excellence in Antarctic Science
- KUM – Specialists at depth
- CSIRO
- KOPRI – Korea Polar Research Institute
- The Tasmanian Polar Network
- Antarctica New Zealand
- COLTO – Toothfish - Sustainable. Healthy. Delicious.
- Joint Task Force – SMART Subsea Cable Systems

OUR SUPPORTERS

- NSF
- Theo Murphy Initiative (Australia)
- POGO – Partnership for Observation of the Global Ocean
- OCEAN:ICE
- Gobierno de Tierra del Fuego Antártida e Islas del Atlántico Sur – Secretaría de Ciencia y Tecnología
- SCAR – Scientific Committee on Antarctic Research
- SCOR – Scientific Committee on Oceanic Research
- SIO
- University of Tasmania – IMAS – Institute for Marine and Antarctic Studies
- Tasmanian Government
- The University of Edinburgh
- OWL LABS
- Tasmanian Museum & Art Gallery
- Business Events Tasmania

OUR EXHIBITORS

- CCAMLR
- CLS Oceania
- echoview
- imbros
- KUM – Specialists at depth

The Australian Antarctic Program Partnership is a $50 million research program funded from 2019 to 2029.

The AAPP improves our understanding of the role of Antarctica and the Southern Ocean within the global climate system and the implications for marine ecosystems.

Through collaborative integrated science, the AAPP aims to inform timely policy responses to climate change. The AAPP is funded by the Australian Government Department of Industry, Science and Resources, led by the University of Tasmania.

www.aappartnership.org.au

The Australian Research Council (ARC) Australian Centre for Excellence in Antarctic Science (ACEAS) is a collaboration between Australian universities, government agencies and international research institutions.

The objective of ACEAS is to help communities to prepare for climate risks emerging from East Antarctica and the Southern Ocean. ACEAS will do this by integrating knowledge of the region's ocean, atmosphere, cryosphere and ecosystems.

Led by the University of Tasmania the program commenced in 2021 and is funded to run until 2025. The program will grow to 37 postdoctoral investigators and 24 PhD candidates.

www.antarctic.org.au

K.U.M. Umwelt-und Meerestechnik Kiel GmbH., over the 2+ decades has supported leading academic and research organisations worldwide by developing and delivering bespoke subsea data acquisition system, offering end-to-end services from concept through to manufacturing; and also turnkey solutions. Pioneers in the manufacture of Ocean Bottom Seismometers (OBS) evolving with new technologies and customized to the needs of our valued customers; we also deliver varied products and services to the institutions involved in deep sea research, polar sciences, offshore oil & gas, subsea exploration and engineering, military and defence, medical equipment etc. K.U.M. India covers the services and solutions in the Indian market and also the region.

"Our vision is to help you make the impossible possible at depth"

www.kum-kiel.de

As Australia's national science agency and innovation catalyst, CSIRO solves the greatest challenges through innovative science and technology.

We work with organisations large and small, delivering world-leading research and development solutions to help their business innovate, improve and grow. Our collaborative research turns science into solutions for food security and quality; clean energy and resources; health and wellbeing; resilient and valuable environments; innovative industries; and a secure Australia and region. With 5,000 experts, state-of-the-art facilities, and a global collaborative research network we bring together the best and brightest minds to drive strategic growth and overcome unique business challenges like no other.

Driven to create and facilitate societal, environmental and economic impact, we work with organisations across all major sectors and at all stages of the innovation lifecycle from strategic advice and planning, research and development, through to commercialisation and funding.

CSIRO. Unlocking a better future for everyone.

www.csiro.au

A journey beginning at the end of the world. Korea Polar Research Institute (KOPRI) is a world-leading polar research institute with state-of-the-art infrastructure, including the ice breaking research vessel Araon, two Antarctic stations, and one Arctic station. KOPRI is committed to conducting high-impact research that attracts global attention, preemptively responds to climate change, and creates future value by utilizing the polar regions.

www.kopri.re.kr/eng

Hobart is the world's leading Antarctic and Southern Ocean gateway and internationally recognised centre of Antarctic excellence.

Drawing on the services and expertise of more than 70 members, the Tasmanian Polar Network provides specialised support to commercial, scientific and government organisations operating in the Southern Ocean and Antarctica.

Services and support available through the Tasmanian Polar Network include:

- polar operations
- specialised equipment
- maintenance and servicing
- transport and logistics

www.tasmanianpolarnetwork.com.au

Antarctica New Zealand is the New Zealand government agency responsible for carrying out New Zealand's activities in Antarctica, supporting world leading science and environmental protection. Our vision is: Antarctica and the Southern Ocean – valued, protected, understood.

www.antarcticanz.govt.nz

COLTO, or the Coalition of Legal Toothfish Operators, represents around 80% of the global toothfish fishing industry. COLTO promotes the sustainable fishing of toothfish, whilst remaining vigilant against potential IUU operations.

COLTO facilitates its Members working together and with others, including through participation and provision of high-quality scientific data to CCAMLR and other bodies.

www.colto.org

The mission of the ITU/WMO/UNESCO-IOC Joint Task Force (JTF) for Science Monitoring and Reliable Telecommunications (SMART) Cables is to have sensors integrated into subsea telecommunications cables become the world standard, leading to a global network for sustained ocean observation, geophysical study of earthquakes, and earthquake and tsunami warning in a world with rising sea levels.

The JTF is working towards contributing to observing the Southern Ocean by connecting the four southern hemisphere continents with SMART Cables.

www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx

CCAMLR

The Convention on the Conservation of Antarctic Marine Living Resources (the Convention) is an international agreement established to conserve Antarctic marine living resources and is an integral part of the Antarctic Treaty system. The Convention applies to all marine living resources within the Antarctic marine ecosystem. The objective of the Convention, set out in Article II, is the conservation of Antarctic marine living resources, where the term 'conservation' includes rational use. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) gives effect to the Convention's objective and its principles of conservation. CCAMLR adopts conservation measures that regulate fishing and related activities in the Southern Ocean in accordance with the Convention's objective and principles of conservation.

CCAMLR Headquarters and the Secretariat are based in Hobart, Tasmania.

www.ccamlr.org

CLS OCEANIA

CLS, a subsidiary of the French Space Agency (CNES) and CNP, is a worldwide company and pioneer provider of monitoring and surveillance solutions for the Earth since 1986. Its mission is to deploy innovative satellite-based monitoring solutions to understand and protect our planet, and to manage its resources sustainably.

www.groupcls.com

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echoview SOUND KNOWLEDGE

Echoview Software is pleased to exhibit at the 2023 Southern Ocean Observing System (SOOS) Symposium.

Echoview is the world's premier software package for hydroacoustic data processing, delivering powerful and flexible capabilities for water-column and bottom echosounder and sonar data processing.

We work with governments, scientists, commercial fisheries, and NGOs globally to support the understanding and sustainable use of aquatic resources.

Visit our exhibition table to find out how we can make your hydroacoustic data processing faster, easier, more objective, and cost-effective.

www.echoview.com

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imbros

With full sales, support and engineering staff, and 50 years of experience supplying oceanographic instrumentation to businesses across Oceania, Imbros is your go-to consult for equipment, support and advice - whatever your needs. Since 1973, Imbros has been Asia Pacific's answer to Ocean Science.

www.imbros.com.au

K.U.M. Umwelt-und Meerestechnik Kiel GmbH., over the 2+ decades has supported leading academic and research organisations worldwide by developing and delivering bespoke subsea data acquisition system, offering end-to-end services from concept through to manufacturing; and also turnkey solutions. Pioneers in the manufacture of Ocean Bottom Seismometers (OBS) evolving with new technologies and customized to the needs of our valued customers; we also deliver varied products and services to the institutions involved in deep sea research, polar sciences, offshore oil & gas, subsea exploration and engineering, military and defence, medical equipment etc. K.U.M. India covers the services and solutions in the Indian market and also the region.

"Our vision is to help you make the impossible possible at depth"

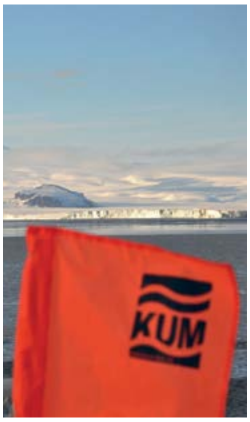
www.kum-kiel.de

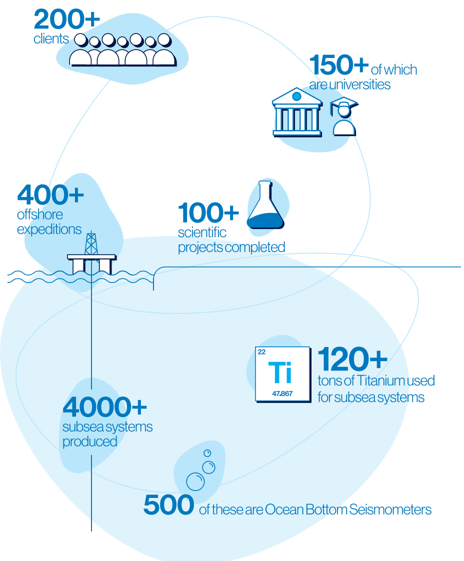
Photo Credit: Esmee van Wijk

Specialists at depth
Creating unique solutions to help you deliver your future vision

For the past two decades, K.U.M. has supported leading academic centres around the world by developing bespoke subsea technology. Today, we are established as the leading provider of subsea data acquisition systems delivering an end-to-end service from conception through to manufacturing.

Our vision is to help you make the impossible possible at depth.





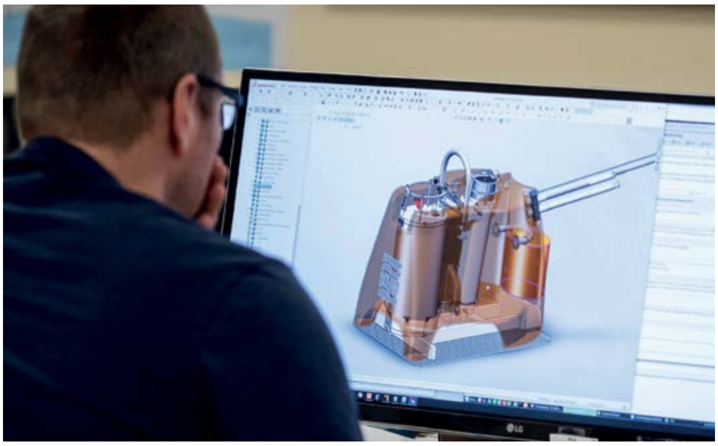
Over the years, our passion for continuous innovation has allowed us to expand our services and our markets. As our solutions have become ever more targeted and specialised, we have streamlined the way deep sea marine data is captured and processed. Across a wide variety of industries, we now help our customers to go further, see better and understand more.

With our vast experience of supporting academic institutes to undertake cutting edge oceanographic research, we are uniquely positioned to create, build and deliver innovative subsea solutions. Solutions designed to meet the challenges of the deep marine environment.

Today, in the offshore energy industry for example, where there is an increased focus on energy transition, cost effectiveness and environmental sustainability, our subsea solutions are arguably more important than ever. For customers seeking new ways to capitalise on future exploration opportunities, we simply bring tomorrow's technology to the table today.

Pioneering subsea solutions
Supporting the world's deep sea explorers to go further

KUM Specialists at depth



We work with some of the world's leading research institutes and major offshore oil and gas companies to deliver innovative technology solutions tailored to the requirements of their specific subsea projects.

In the offshore deep sea environment, these customers demand high performance technology that maximises the use of funds, time and manpower. Our pioneering science-led solutions help to keep our customers one step ahead of the competition.

Ongoing research helps us to imagine the future for clients who need to constantly evolve to meet new challenges. Issues currently being tracked for customers include the tightening of environmental policies, the exploration of new geographies, and the growth of automation. At the same time, our future-scanning looks at development in areas such as microelectronics, enhanced data transfer and artificial intelligence. With all this and more in mind, we're primed to be the subsea partner who can help our customers meet the demands of the modern era.

Knowledge, insights and experience
Our understanding of this new operational landscape is derived from first-hand knowledge of developing end-to-end solutions from the ground up. A combination of unique insights and in-field experience means that we are ideally positioned to integrate new technologies across exploration boundaries.

Indeed, as a world leader in marine research and subsea engineering, we don't only invest in R&D to enhance our current systems, we also seek to anticipate our customers' future needs. For example, by advancing the use of low frequency passive seismic technology alongside ocean bottom seismometers (OBSs), we are rapidly altering the way seismic data is captured and analysed. Our innovative solution simultaneously complements traditional methods and significantly reduces the drilling risks.

What we offer you
Unique insights, in-field experience and innovative technology

Consistent Quality
This is the cornerstone of everything we do and deliver. Anything we design will work exactly as you expect it to.

Complete Service
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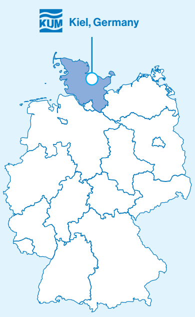

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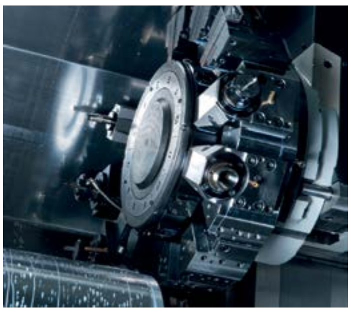

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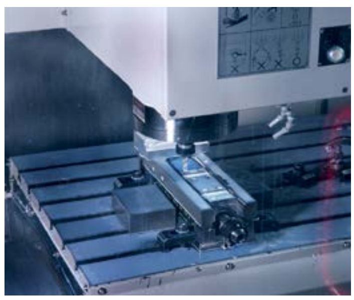

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ORAL ABSTRACTS

ORAL SESSION CONTENTS

Southern Ocean sea ice variability in a warming climate: observations and modeling approach – Part 1

Increased Antarctic sea ice variability and its drivers

Dr Will Hobbs[1], Dr Paul Spence, Dr Ed Doddridge, Dr Amelie Meyer, Dr Serena Schroeter, Dr Alexander Fraser, Dr Philip Reid, Ms Tian Tian, Dr Zhaohui Wang, Dr Guillaume Liniger, Prof Philip Boyd

[1]Australian Antarctic Program Partnership, Australia

Recent extreme events have dominated Antarctic sea ice research in recent years, which is likely to continue with last month's record low sea ice cover, the second such record in as many years. These warm extremes are remarkable, but it's also notable that they were preceded by record high sea ice cover in 2014. In this talk, I will present evidence that over the last 15 years there has been an apparent increase in Antarctic sea ice variability, not just a tendency to low extremes. Tied to that change, our analysis also shows that the Antarctic sea ice response to major climate modes (SAM, ENSO, Amundsen Sea Low and Zonal Wave 3) has altered, such that those modes alone do not seem to explain recent sea ice variability. Curiously, ocean warming does not appear to explain the changed variability either. Instead, we argue that long term sea ice trends have resulted in this changed response. Summer sea ice cover in the Amundsen-Bellingshausen sector significantly reduced over the satellite era, leading to an almost halving of sea ice variance since 2006 in the same Amundsen-Bellingshausen sector. As a result, the sector no longer compensates for the variability of sea ice in the Weddell Sea, and the Weddell Sea now dominates the total Antarctic sea ice cover variability. Weddell Sea ice is more strongly influenced by transient atmospheric variability (e.g., storms) than large scale modes (e.g., such as the Southern Annular Mode) and as a result those modes now have less skill at explaining summer Antarctic sea ice events. An important aspect of this work is its reliance on modelling tools, due to the limited observing network on the Antarctic continental shelf.

An abrupt transition in Antarctic sea ice–ocean system

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Over the past decade, Antarctic sea ice extent exhibited a sequence of record maxima, followed by a rapid decline in 2015/16, and record minima since. In this presentation, we show that this sudden and remarkable ice loss marks an abrupt transition from a high to a low ice state that cannot be explained by year-to-year variability. Instead, it is most likely associated with a longer term variability arising from ice–ocean feedbacks and subsurface ocean warming. The abrupt transition was preceded by an increase in persistence and variance of the sea ice anomalies, an increasing upper Southern Ocean density stratification, and an accumulation of heat at the subsurface; suggesting a decoupling of the surface from the subsurface ocean. During this period, the sea ice anomalies shifted from being structured predominantly regionally and seasonally to a largely circumpolar and interannual regime. In 2015/16, the upper ocean density stratification in the ice-covered region suddenly weakened, leading to a release of the heat from the subsurface, contributing to the sea ice decline during winter. Our analysis suggests that the sudden sea ice loss in 2015/16, and the persisting low ice conditions since, arose from a systematic change in the physical state of the coupled circumpolar ice–ocean system. This change will have wide implications for global climate, ecosystems, and the Antarctic Ice Sheet.

Is the Antarctic sea ice already sweating? A glimpse into recent in-situ ice and snow data in the Weddell Sea

Dr. Stefanie Arndt[1], Mara Neudert[1], Christian Haas[1]

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The Antarctic sea ice cover is subject to considerable spatial and temporal variability, which affects processes and interactions between the atmosphere, sea ice and ocean, and is therefore a key driver for Southern Ocean climate and ecosystems. While recent climate model simulations indicate a decrease in Antarctic sea ice extent over the past few decades, the observed sea ice evolution shows a contrasting trend, with a decrease only being observed since 2016. The precise reasons for the differences in projected sea ice extent and the associated effects of dominant interactions with other components of the climate system are not yet understood. The presence of snow on the ice throughout the year significantly modifies these interactions by affecting the ice mass balance and associated heat fluxes.

Due to the coexistence of seasonal and perennial sea ice, the Weddell Sea is an ideal region to investigate the possibility of a regime shift and its potential effects on sea ice and snow cover properties. Therefore, we provide a comprehensive compilation of in-situ observations of physical sea ice and snow cover properties collected during numerous expeditions to the Weddell Sea since the 1990s.

Our results indicate that there have been no significant changes in sea ice and snow thickness or internal properties over recent decades. Furthermore, similar surface energy fluxes are calculated throughout the study period, leading us to propose that the low sea ice extent since 2016 is not a result of atmospheric heat flux anomalies.

Measuring up: Antarctic sea ice in the Earth system

Dr Petra Heil[1], Mr Sean Chua[1], Mr Xinlong Liu[2], Dr Rachel Tilling[3], Dr Stuart Corney[2]

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While satellite observations provide meso-scale sea-ice concentration, technology to observe sea-ice thickness across large scales is less well verified. In recent years both laser and radar altimetry has been used to obtain total or ice freeboard measurements as proxy for sea-ice thickness. Recently inroads have been made for the freeboard to sea-ice thickness conversion for the Arctic. However, due to subtle differences in the amount and composition of the snow cover on Antarctic sea ice, these methods do not translate for sea ice in the Southern Ocean. Here we discuss a number of measurement approaches and how to combine these to derive sea-ice thickness products with sufficient accuracy to be useful as initialisation or for assimilation into forward numerical models, including for tactic sea-ice forecasts or longer-term climate modelling.

The complexities of estimating sea-ice production from field observations with implications for model-based estimates and for ice-climate and ice-ecosystem interactions

Dr. Sharon Stammerjohn[1], Steve Ackley[2], John Cassano[1], Peter Guest[3], Brice Loose[4], Ted Maksym[5], Madison Smith[5], Pete Sedwick[6], Jean-Louis Tison[7]

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Antarctic sea ice production is driven by atmosphere-ocean-ice interactions involving both thermodynamical and dynamical processes. Here we present a summary of satellite-, autonomous- (underwater and aerial), and ship-based estimates of sea ice production, the latter includes a variety of approaches derived from different combinations of atmosphere, ocean, sea-ice, and geochemical observations acquired during a late autumn/early winter field campaign in the Ross Sea in 2017 during the PIPERS expedition. The approaches range from instantaneous estimates to seasonally/regionally averaged estimates, involve different assumptions and conditions, and underscore the inherent challenges and complexities of making such field measurements, not to mention accurately capturing the physical processes that drive sea-ice production in climate model simulations. We then place the 2017 sea-ice production estimates within the larger context of the unique conditions that took place in the Ross Sea during 2017 -- an exceptionally low autumn/winter sea-ice season, initiated by a 2-month delayed autumn ice-edge advance. Since the austral spring of 2016, sea-ice extent has largely remained below the long-term mean, both in the Ross Sea as well as for the Antarctic-wide mean, signaling a possible shift in atmosphere-ocean-ice interactions. Various climate drivers are discussed, as well as implications for ice-ecosystem interactions including within the Ross Sea Marine Protected Area.

East Antarctic Coastal Current and its influence on summertime sea ice distribution

Dr Phil Reid[1,2], Dr Rob Massom[2,3,4]

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Here we closely examine a new climate and environmental index and metric that enables daily circumpolar mapping, quantification and monitoring of the extent of Antarctic coastline that is free of sea ice – or coastline that is "exposed" to open-ocean conditions and waves. The time series reveals previously-unknown climatological patterns and trends of coastal exposure around Antarctica. Notably and across much of the East Antarctic coastline, there has been a 1979-2020 trend towards less exposure, or to put it another way, more persistent sea ice through summer. Of particular note is a westward progression of this trend pattern of approximately 20° of longitude in autumn (March through May). We present an analysis of these trends and their westward progression. We then use this analysis to explore how an event, such as the calving of a large iceberg, in one region across East Antarctic may influence the regions "downstream" via the westward-flowing Antarctic Coastal Current.

Human Engagement with the Southern Ocean: Science, Tourism, Environment

Citizen Science in the Southern Ocean: Tourist Perspectives

Dr Hanne Nielsen[1], **Professor Elizabeth Leane**[1], Associate Professor Anne Hardy[1], Professor Can Seng Ooi[1], Dr Carolyn Philpott, Ms Katie Marx

[1]University of Tasmania, Australia

Tourism is the main way humans interact with Antarctica and the Southern Ocean. It also increasingly offers a platform for scientific observations and interactive activities to take place. This presentation examines how interactive citizen science activities impact visitors' attitudes towards Antarctica, and how these activities could be designed to maximize positive change. Following an overview of the history of Citizen Science in the Antarctic, we present findings from a 2022/23 field season in the Antarctic Peninsula in the 2022/23 aboard the MS Fridtjof Nansen. Two researchers interviewed 41 guests in situ on the way south and again during the return. Questions related to perceptions of Antarctica, motivations for travel, participation in science activities, and what guests had learnt during the expedition. Here we examine guest perceptions of citizen science in Antarctica and whether the science program played a role in motivating travel choices and mediating the Antarctic environment for our interviewees. Our research suggests that greater scientific understanding of the region gained during the trip also led some guests to question whether their travel choices as environmental concerns came to the fore. It appears that while citizen science can augment the Antarctic tourist experience, it also elicits questions about human impacts on the environment more broadly.

Public Support for Antarctic and Southern Ocean Science in Australia: Lessons from a National Survey

Professor Bruce Tranter[1], **Prof Elizabeth Leane**[1]

[1]University of Tasmania, Hobart, Australia

The Antarctic and Southern Ocean (ASO) region is featuring more and more in public discourse around anthropogenic climate change. Media reports on ice loss and instability in and around the continent appear almost daily. This heightened media presence has been underscored by intergovernmental initiatives, such as the Antarctic Treaty Consultative Parties' recent adoption of resolutions to promote awareness of climate change impact and research in the Antarctic region to government agencies and the general public. However, the effectiveness of such exhortations is difficult to measure. Despite increasing scholarly interest in public knowledge, opinions and attitudes in relation to the Antarctic region, robust empirical data is limited and piecemeal.

In this paper, we report on findings from a nationally representative survey of public support for ASO science of just over 1000 adults in Australia, conducted in 2021-22. Our primary research aim was to determine the extent to which various sectors of the Australian public support Antarctic research and related infrastructure, as manifested in current high-profile government research investment. We addressed this aim by including four questions in the 2021 Australian Survey of Social Attitudes. Each question asked respondents about their level of support for a particular national Antarctic research initiative undertaken by the Australian Antarctic Division. The questions focussed on initiatives that were topical and prominent in the media before and during the period of the survey: a proposal for a concrete runway at a continental station; a new icebreaker; krill research; and ice-core research. While these activities in no way reflect the full spectrum of ASO research and related infrastructure supported by Australia, together they elicited both an overall indication of public support and a useful picture of the ways in which support varies between particular segments of the public for specific projects.

Key results reinforce earlier findings in other national contexts – for example, that older people and men are more likely to support Antarctic scientific research than younger people and women. They also reveal new information, including a correlation between particular sources of media coverage and support for ASO research. Our detailed focus on specific kinds of research and research infrastructure reveals a complex picture in which support for certain projects varies with party-political allegiance and other factors in ways that might initially seem counter-intuitive. We suggest some cultural and historical influences that might explain these results.

Our data has implications for where and how the public engagements efforts of government agencies and NGOs could most usefully be applied. While the survey is focussed on Australia, it points to complexities around public support for ASO research that could be productively investigated in other national and in international contexts. With the UN Southern Ocean Decade Action Plan emphasing the need for "an inspiring and engaging Southern Ocean where society understandings and values the ocean", understanding public support for research in the region is increasingly important.

FjordPhyto: A citizen science project that enriches travelers experience in Antarctica

Ms Allison Cusick[1], Martina Mascioni[2], Brooke Dixon[3], Daniela Cajiao[4], Robert Gilmore[5], Ted Cheeseman[6], Maria Vernet[1]

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As part of the educational opportunities provided onboard tour expedition vessels, Citizen Science (CS) projects are the most prominent opportunity to engage in polar science. The International Association of Antarctica Tour Operators (IAATO) reported that more than 100,000 travelers are expected to arrive to Antarctica during the 2022-2023 season. Since its foundation, IAATO advocates for sustainable tourism activities to avoid potential threats and impacts to the ecosystem while providing travelers unique, educational, and transformative experiences. FjordPhyto is a CS project where travelers gather data for five months each season to help researchers look at changes in phytoplankton (microalgae) response to melting glaciers. Since its conception in 2016, FjordPhyto has involved more than 4,000 Antarctic travelers who contributed hundreds of in-water observations and samplings. During two consecutive seasons (2017-2018 and 2018-2019), 81 voluntary feedback surveys were collected from participants to understand their perception and engagement with the FjordPhyto program onboard. Analyses of survey data reveal that 97% of respondents felt that participating in CS enriched their travel experience. Results show that 'educational' was the most identified concept in responses when prompted to describe how their experience was enriched by CS engagement. Participants most frequently expressed an 'appreciation for scientific learning' or more specifically, for 'learning about ecosystems and climate change' after participating. This exploratory study provides a first understanding of how CS projects, like FjordPhyto, have a positive impact on the Antarctic Tourism experience.

Stories of the far south: Why Antarctica needs an intersectional lens.

Ms Kimberly Aiken[1]

[1]University of Tasmania, Hobart, Australia

Antarctica has historically been synonymous with whiteness and heroic male stories of conquest. And yet this history of Antarctica is not representative of the global population - a wider range of stories need to be told. The ethnic majority, Black, Brown, and Indigenous people, comprise 85 percent of the global population yet remain vastly underrepresented in the continent's past and present. Antarctica remains predominately white across all work sectors and historical and modern-day scholarship. The continent is dissociated from racial, ethnic, and cultural contributions and representation. Withheld from historical Antarctica are contributions by unrecognized groups of people, narratives, and expeditions only recognized and accounted for centuries later. Today, a growing body of scholarship recognizes oral historical accounts of Māori Indigenous connections to Antarctica as early as the 17th century with current Māori involvement in Antarctic expeditions; however, it is contested by western Antarctic epistemology. Systemic barriers have and continue to preclude the ethnic majority from accessing and engaging with the continent in different ways through tourism, expeditioner recruitment, science and research, and trade. In this presentation, I argue that post-colonial approaches to Antarctica address the intersection of science, class, and gender, yet race and ethnicity remain the most understudied intersectional analysis considered in any Antarctic context. A literature review will collate stories of underrepresented contributions and present a review of voices not heard before in Antarctic history. I present a model for how intersectionality, an analytical framework used to understand multiple factors of advantage and disadvantage across a web of interconnected social identities, can generate multicultural stories of Antarctica that have so far been overlooked, contributing to a richer tapestry of human engagement with the region.

From historical humpback whale catch data to climate model evaluations in the Southern Ocean

Prof Marcello Vichi[1], Dr Elisa Seiboth[2], Prof Kenneth Findlay[3], Ms Cherry Allison[4], Dr Olaf Meinecke[5]

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The assessment of historical environmental conditions in the Southern Ocean is limited by the poor availability of oceanographic records during the 20th century, up until the advent of 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 at the time of capturing. Although the impact of commercial whaling makes difficult to disentangle the drivers of the spatial and temporal distributions of whales, these data have been used in the past as proxy for the location of major ocean features. Using historical whale records in the oceanographic context is hampered by the different whaling practices and the scattered or incomplete written documents. However, the selection of certain species that have a known relation with their habitat can give us indication of the larger scale Southern Ocean features. This is the case of humpback whales, which have been severely decimated during the first decades of the 20th century. This species is usually found in open waters adjacent to the sea ice edge, which makes it the most suitable candidate for assessing the northward extent of sea ice in a period of complete data absence at the circumpolar scale. We report on the transdisciplinary approach used to combine historical whale catches with sea-ice model simulations from the Climate Model Intercomparison Project phase 6 (CMIP6) during the historical period 1920-1970. We found that the reconstructed sea-ice edge from about 100 years ago is located northward of the regions in which humpback whales where historically caught. This Southern Ocean story is therefore informing us that tuning and assessing climate models only using satellite-era observations lead to an overestimation of Antarctic sea-ice extent earlier in the century, which may impact on our future predictability.

Updates on the SCAR Antarctic Biodiversity Portal GBIF Hosted Portal

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The SCAR Antarctic Biodiversity Portal (biodiversity.aq) is the regional node of the Ocean Biodiversity Information System (OBIS) and the Global Biodiversity Information Facility (GBIF). Started in 2005 as the SCAR-MarBIN. it has and continues to offer various tools to the Antarctic Research Community.

Here we present a new portal developed in collaboration with the GBIF Secretariat.

This new GBIF initiative lowers the technical threshold for maintaining a branded web presence displaying a targeted subset of the data and information already available through GBIF.org.

The portal is designed to provide access to information on the biodiversity of the Antarctic region, including occurrence data and taxonomic information. The antarctic biodiversity in the portal adheres to the FAIR (Findable, Accessible, Interoperable and Reusable) principle. This presentation will discuss the features of the SCAR Antarctic Biodiversity Portal and how it can be used to support research and conservation in the Antarctic and Southern Ocean region

Plankton Diversity, food web dynamics and biogeochemical cycle in the Southern Ocean

Physical-biological drivers modulating phytoplankton seasonal succession along the Northern Antarctic Peninsula

Mr. Raul Rodrigo Costa[1], MSc. Afonso Ferreira[2], Dr. Márcio Souza[1], Dr. Professor Virginia Tavano[1], Dr. Professor Rodrigo Kerr[1], Dr. Professor Eduardo Secchi[1], Dr. Professor Vanda Brotas[2], Dr. Tiago Dotto[3], Dr. Professor Ana Brito[2], Dr. Professor Carlos Mendes[1]

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The Northern Antarctic Peninsula (NAP) shows shifts in phytoplankton distribution and composition along its warming marine ecosystems. However, despite recent efforts to mechanistically understand these changes, little focus has been given to the phytoplankton seasonal succession, remaining uncertainties regarding to distribution patterns of emerging taxa along the NAP. To fill this gap, we collected phytoplankton (pigment and microscopy analysis) and physico-chemical datasets during spring and summer (November, February and March) of 2013/2014 and 2014/2015 off the NAP. Satellite measurements (sea surface temperature, sea ice concentration and chlorophyll-a) were used to extend the temporal coverage of analysis associated with the in situ sampling. We improved the quantification and distribution pattern of emerging taxa, such as dinoflagellates and cryptophytes, and described a contrasting seasonal behavior and distinct fundamental niche between centric and pennate diatoms. Cryptophytes and pennate diatoms preferentially occupied relatively shallower mixed layers compared with centric diatoms and dinoflagellates, suggesting differences between these groups in distribution and environment occupation over the phytoplankton seasonal succession. Under colder conditions, negative sea surface temperature anomalies were associated with positive anomalies of sea ice concentration and duration. Therefore, based on sea ice–phytoplankton growth relationship, large phytoplankton biomass accumulation was expected during the spring/summer of 2013/2014 and 2014/2015 along the NAP. However, there was a decoupling between sea ice concentration/duration and phytoplankton biomass, characterizing two seasonal periods of low biomass accumulation (negative chlorophyll-a anomalies), associated with the top-down control in the region. These results provide an improved mechanistic understanding on physico-biological drivers modulating phytoplankton seasonal succession along the Antarctic coastal waters.

The effect of iceberg melt on nutrient stoichiometry and primary producers.

Dr Mark Hopwood[1], Dr Mireia Mestre[2], Dr Juan Höfer[3]

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Around the Antarctic coastline, glaciers are a significant source of freshwater and lithogenic material to the ocean. With increasing annual fluxes of runoff and calved ice, it is unclear how these glacial outflows will affect primary producers in the future ocean. In addition to physical effects from icebergs mixing the water column, the release of high sediment loads may negatively affect light availability or prove fatal to grazers. Conversely the release of trace metals associated with iceberg melt could have fertilizing effects on phytoplankton. By combining an extensive compilation of 500 ice melt samples for (micro)nutrient content with incubation experiments in the Western Antarctic Peninsula (WAP) to test the response of phytoplankton communities to increasing freshwater and sediment, we aim to increase understanding of cryosphere-ocean linkages.

Whilst iceberg melt was consistently found to act as a modest source of (micro)nutrients, particularly the bioessential trace metals iron and manganese (mean concentrations 88 nM dFe, 29 nM dMn, 0.64 μM dSi), the response of primary producers in WAP coastal seawater to increasing meltwater was limited suggesting trace metal concentrations were already replete in the water column. Furthermore, a negative response was observed when salinity declined by more than 2 psu suggesting primary producers were poorly adapted to pulses of low salinity. Trace metal spikes similarly had limited effects corroborating the hypothesis that inshore waters are (micro)nutrient replete. The addition of small to moderately high sediment loads, up to 500 mg L-1, did however produce a positive effect on chlorophyll a, and notable shifts in bacteria and eukaryote abundances. Given the lack of response to trace metal additions, this points towards the multiple mechanisms via which suspended sediment affects ecosystem dynamics which may include hosting bacterial communities, a decrease in viral load, grazing suppression and shading in addition into moderating micronutrient availability.

Plankton diversity and dynamics in the upper surface of the Indian sector of Southern Ocean ecosystem: biogeochemical implications

Mr Athirpankandi Sreerag[1],[2], Dr R K Mishra[1], Dr R K Naik[1], Dr Vankara Venkataramana[1], Dr Melena Soares[1]

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In the Southern Ocean marine ecosystem, the sink of CO2 and climate changes are associated with the shifting of the plankton communities with potentially wide-ranging biogeochemical effects. The physical-chemical parameters such as the temperature, photosynthetically available radiation (PAR), and nutrients collectively influence to adjust the plankton diversity. Significant latitudinal phytoplankton variations were observed at the Subtropical Front (STF), Sub Antarctic Front (SAF), Polar Front (PF), and South of Polar Front (SPF) during the austral summer of 2019. The Fragilariopsis spp. of diatoms (~ 5 x 10□ Cells L^{-1}) was dominant and followed by Chaetoceros sp. (~ 1 x 10□ Cells L^{-1}) and Coscinodiscus sp. (~ 5 x 10□ Cells L^{-1}) at the surface from SAF to SPF through PF. While the Gyrodinium spp. (~ 2.4 x 10□ Cells L^{-1}) of flagellates was most dominant and followed by Protoperidinium sp. (~ 2 x 10□ Cells L^{-1}) at the surface of STF. Zooplankton biovolume in the upper 200m was varied between 0.71 – 10 ml 100 m^{-3}. Relatively higher zooplankton biovolume and numerical abundance have been found in the SAF than in PF. The nitrate (NO□-), phosphate (PO□^{3}-), and silicate (SiO□□-) concentrations were higher towards high latitudes. Lower zooplankton biovolume was associated with high Chlorophyll a (Chl-□) concentration and showed negative consequences for higher trophic levels in the PF. The results suggest that the phytoplankton biomass and community compositions vary along the frontal regions due to the combined impact of governing variables and therefore have regional biogeochemical implications.

Inter-annual variability of POM dynamics and its implications on the biological pump in the Indian sector of the Southern Ocean

Dr. Melena Soares[1], Dr N. Anilkumar[1], Dr R.K. Mishra[1], Dr. P. Sabu[1], Dr. V. Venkataramana[1], Dr. R.K. Naik[1], Dr. R. Chacko[2], Dr. A. Sarkar[3]

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The carbon biological pump is a crucial part of the oceanic carbon cycle and its efficiency is critical in determining the long-term sequestration of carbon into the ocean. This study attempts to address the variability in the efficiency of the biological pump across the different fronts of the Indian sector of the Southern Ocean based on particulate organic matter (POM) dynamics. The study also addresses the inter-annual variability in the composition and possible fate of POM in the Indian sector of the Southern Ocean (ISSO).

The elemental and isotopic composition of POM displayed a strong frontal variability in the ISSO during all observational years. Additionally, it was observed that some regions supported a regenerative system, which differed temporally during the study periods and determining the fate of POM. This work suggests that oceanic changes and nutrient abundance amends the biological processes and the biological community structure, while these factors strongly control the inter-annual and frontal variation in the POM composition and transformation in the ISSO. The subtropical frontal region showed the most inter-annual variation with regard fate of POM in the upper water column. This was attributed to sporadic events like eddy activity, that altered the hydrography, biochemical processes and the POM dynamics of the region. Furthermore, secondary features like sea-ice cover, eddies, sea surface temperature, etc. had an considerable role in triggering changes in the biogeochemical processes and food-web dynamics responsible for the inter-annual variation of POM composition and fate, thus influencing the efficiency of the biological pump. Overall, this study also implied that the POM dynamic and the efficiency of the biological pump was largely controlled by front specific factors in the ISSO during austral summer.

Macrozooplankton food-webs across the South Georgia shelf region, and their relationship to Antarctic krill abundance

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The South Georgia continental shelf break is a highly productive and biodiverse region of the Southern Ocean, with a thriving community of macrozooplankton. Whales, seals and marine birds all rely on this abundance of macrozooplankton. This high level of biological activity contributes to the large drawdown of atmospheric carbon in the region and its passage to deep ocean layers. South Georgia also has commercial fisheries for finfish and Antarctic krill (Euphausia superba, hereafter krill). This region is remote from the core populations of krill to the south but the species, nevertheless, reaches high levels of abundance here. These large populations do not occur in isolation but must co-habit these waters with the rest of macrozooplankton community. In this presentation, we analyse an 11 year time series of spatially extensive net samples to examine differences in the macrozooplankton communities on and off the shelf break, as well as patterns of variability over time. We found that total catch (community) abundance did not vary significantly across regions with or without the inclusion of krill. There was an overall trend of the onshore region being more variable in community composition. Krill was strongly associated with this onshore region, in line with previous studies. Community composition in the offshore environment was less variable and more species rich compared to the onshore community. Less krill was associated with the offshore region. We propose that the onshore and offshore environments have different, if overlapping, food-webs. These communities appear to be relatively stable independent of the presence or absence of krill, either spatially or temporally. As the Southern Ocean represents an area particularly vulnerable to climate change, the overlap and gradients in species distribution seen here highlights the complexity in predicting potential impacts on community structure, and subsequently on biogeochemical cycles.

Diversity patterns of prokaryotic communities in the Scotia Sea and Bransfield Strait during summer 2019

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Diversity of marine prokaryotes (Bacteria and Archaea) is key to understand Earth system. Yet, this diversity has been described mainly in tropical, subtropical and temperate oceans, and knowledge about the diversity of prokaryotes in the polar areas is still scarce. The aim of this study is to describe the diversity of prokaryotes in the Southern Ocean, concretely in the Bransfield Sea and Scotia Sea. For this, samples were collected at different depths, from the epipelagic to the bathypelagic, and were separated in three size-fractions (pico, nano and micro). We analyzed bacterial diversity with Illumina and bacterial abundances with cytometry. We observed that prokaryotic abundances decreased from northern stations to southern stations and decreased in depth in all stations. Synechoccocus (measured with cytometry) disappeared completely in high-latitude stations. Scotia Sea was the most diverse area and diversity increased with depth in all stations. Diversity decreased with the size-fractions in surface waters, whereas increased with the size-fraction in deep waters. Community composition varied clearly between size-fractions and depth, but differences between areas were less evident. The most abundant Phylums were: Bacteroidetes, Planctomycetes, Proteobacteria, Thaumarchaeota, and Verrucomicrobia. All those patterns reported in this study contrast with others found at other latitudes. All this together indicates the singularity of the polar ecosystems and contributes to a better understanding of the ecology of marine microorganisms.

Risks of Poleward Expansion of Harmful Dinoflagellates in the Southern Ocean

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A poleward shift of the phytoplankton species driven by ocean warming has been observed in many waters. As harmful dinoflagellate species have expanded in the Arctic Ocean and caused ecological problems, the trend of the harmful dinoflagellates in the changing Southern Ocean is still not clear. We conducted in situ shipboard iron enrichment incubation experiments in the Ross Sea and Amundson Sea. The results showed that all the samples in the low biomass water quickly responded to the +Fe by increasing photosynthetic activities, and bloomed after about one week after adding Fe. However, the dominant phytoplankton species varied at different stations. In general, the relative abundance of dinoflagellates and Microcystis increased, but the relative abundance of diatoms decreased. Considering the ecological function of dinoflagellate and Microcystis, iron enrichment may not effectively increase carbon flux from sinking phytoplankton biomass, but increased the risk of causing harmful algal blooms. Karlodinium veneficum, a harmful dinoflagellate, was found in high abundance in 3 of the stations. Under the stress of climate change, the dinoflagellates from temperate waters may invade the Southern Ocean, and increase the ecological risks of iron enrichment activities.

Microplastic studies in the coastal waters of South Australia

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Microplastics are present in marine environments worldwide, from the tropics to polar areas, and are of concern because of their ability to enter marine food webs. The present study was implemented through a joint research project between SARDI and Flinders University. The main aim of the research was to assess the distribution of microplastics at a potential "garbage patch" in the Gulf Saint Vincent (South Australia). This aim was identified following the outcomes of particle-tracking computer modeling undertaken by our teams, which has identified areas of plastic accumulation in the Gulf.

The samples were collected monthly from January 2023 onboard RV Bungaree using 5L Niskin bottles at the surface and bottom horizons. In the laboratory, water samples were filtered through metal sieves (20 µm – 5 mm) and the retained fraction was passed through a membrane (0.45 µm). The abundance and types of microplastics were assessed under a Zeiss stereomicroscope Axiolab 5 and the polymer types were analyzed under Horiba Raman spectroscopy with ANFF. The preliminary results have shown that fibers and fragments are the most abundant types of microplastic found in the studied area, which numbers reach 20-50 particles·L-1. As the Integrated Marine Observing System (IMOS) Microplastic facility conducts quarterly sampling at another site in the Gulf, a methodological comparison is being undertaken to optimize sampling efforts in the future. The obtained results will be deposited into the IMOS/AODN (Australian Ocean Data Network) portal for ocean data, so they are available to the broader scientific community. Our previous studies of freshwater streams and the present study provide a basis for future plastic waste management policies and strategies in South Australia.

Observations to understand ocean dynamic processes

Observational evidence of cold filamentary intensification in an energetic meander of the Antarctic Circumpolar Current

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Mesoscale eddy stirring generates finescale filaments, visible in submesoscale-resolving model simulations and high-resolution satellite images of sea surface temperature and ocean colour. Submesoscale filaments have widths of O(1-10 km) and timescales of hours to days, making them extremely challenging to observe. Despite their relatively small scale, submesoscale processes play a key role in the climate system by providing a route to dissipation; altering the stratification of the ocean interior; and generating strong vertical velocities that exchange heat, carbon, nutrients, and oxygen between the mixed layer and the ocean interior. We present a unique set of in-situ observations of a standing meander of the Antarctic Circumpolar Current (ACC) that support theories of cold filamentary intensification – revealing enhanced vertical velocities and evidence of subduction and ventilation associated with finescale cold filaments. We show that these processes are not confined to the mixed layer; they can extend to deep into the ocean interior in regions like the ACC – with strong lateral density gradients, deep-reaching currents, and energetic meanders. The cold filaments are drawn up into an eddy dipole structure associated with the meander and may act as a transport pathway for water mass properties to be carried across mesoscale fronts, into eddies downstream, and into the ocean interior.

Physical controls on ventilation and air-sea exchange in Drake Passage

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Drake Passage is a key region for tracer exchange between the atmosphere, ocean mixed layer, and interior ocean, but mechanistic understanding of this exchange remains immature. Here, we present results from submesoscale-resolving hydrographic transects from the Antarctic Circumpolar Current as well as numerical modeling results from ECCO-Darwin data-assimilative biogeochemistry model. We find that despite strong surface wind and buoyancy forcing that would typically induce ventilation, a non-locally sourced freshwater lens suppresses surface-interior exchange south of the Polar Front. In fact, ventilation between the surface and interior ocean is localized to the Polar Front, where surface eddy diffusivity is modulated at sub-50 km scales. In terms of air-sea exchange, the enhanced vertical stratification resulting from the freshwater lens caps carbon exchange south of the Polar Front, but meandering of the front results in annual variability in carbon outgassing. These results show that ventilation and carbon exchange is sensitive to mesoscale and submesoscale motions and that previous estimates of air-sea heat and carbon fluxes made primarily from Drake Passage extrapolated circumpolarly may not present an accurate picture of heat and carbon fluxes in the Southern Ocean.

Mixing and water mass modification over Discovery Bank, in the Weddell Scotia Confluence of the Southern Ocean

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Seamounts in the Southern Ocean, through their interaction with deep-reaching geostrophic flows and barotropic tides, play a key role in mixing and water mass transformation, important processes in the global Meridional Overturning Circulation. The Weddell-Scotia Confluence (WSC), which separates the Antarctic Circumpolar Current (ACC) to the north from the Weddell Gyre (WG) to the south, lies above a region of highly complex topography, including the seamount of Discovery Bank. Here, we present results from a targeted experiment over Discovery Bank in early 2019, incorporating ship-based CTD, lowered ADCP and microstructure measurements, glider sections and fine-scale velocity data from two EM-APEX floats. While the CTD, ADCP and float data demonstrate the large-scale flow is consistent with a stratified Taylor-column structure that retains water over the seamount for long periods, there are regions of the seamount where the float trajectories "loop", and where under where vertical shear and dissipation of turbulent kinetic energy is enhanced by up to two orders of magnitude compared with background levels. In these areas, the slow "blending" of the seamount on the flows is short-circuited by more rapid turbulent mixing processes, quickly mixing out the mid-depth temperature maximum in the Circumpolar Deep Water via enhanced heat fluxes. The floats and CTD/VMP stations have identified the key locations of this enhanced mixing as being along the southern flank of the bank, and analysis of a tidal model suggests these locations are preferential locations

for the generation of internal tide-driven mixing, primarily of semidiurnal frequency. We are currently evaluating the relative importance of these mixing "hotspots" for modification of the three constituent water masses of the confluence.

How much Upwelling occurs in the Abyssal Bottom Boundary Layer?

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We examine

(i) what sets the vertical stratification in the abyssal ocean, and

(ii) the rate of upwelling of water in the bottom boundary layer of the abyssal ocean. We restrict attention to the bottom-most, densest, 2000m of the ocean and analyse the buoyancy budget in buoyancy coordinates, taking into account the bottom-intensified nature of the rate of diapycnal mixing in the ocean. This bottom-intensified nature of diapycnal mixing means that the diapycnal velocity in the ocean interior is downwards towards denser fluid, and all the diapycnal upwelling occurs in the first ~50m above the sea floor, with the upwelling transport in this Bottom Boundary Layer often being two or three times the net diapycnal upwelling needed to balance the sinking transport of Antarctic Bottom Water.

The geometry and conservation equations of this problem can be described as a steady-state filling-box problem. The rate of sinking of dense Antarctic Bottom Water and the area-integrated diffusive buoyancy flux across the upper-most buoyancy surface are both regarded as given input parameters, which gives the buoyancy contrast between the sinking Antarctic Bottom Water and the value of buoyancy on this upper-most surface. We show that the vertical stratification in the interior abyssal ocean is then entirely determined by knowledge of the rate of detrainment (or entrainment) of plume fluid out of (into) the sinking plume and into (out of) the ocean interior. This knowledge is equivalent to knowledge of the area-integrated diffusive buoyancy flux on the buoyancy surfaces in the abyss.

Because of the (strongly implied) detrainment of fluid from the sinking Antarctic Bottom Water plume, the vertical stratification in the abyss is two or three times that given by the natural buoyancy scale of the problem, namely the ratio of the area-integrated diffusive buoyancy flux to the net upwelling transport through the upper-most buoyancy surface.

Simple expressions are developed for the ratio of the upwelling transport in the Bottom Boundary Layers to the net diapycnal upwelling. These expressions are written either in terms of the observed buoyancy of the sinking Bottom Water plume, or in terms of the rate of detrainment from the Bottom Water plume.

Revisiting circulation and water masses over the East Antarctic margin (80-150°E)

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Full-depth hydrographic sections of the BROKE experiment in 1996 (across the Antarctic margin from 80–150°E; Bindoff et al., 2000) were first revisited by R/V Kaiyo-maru during the 2018/2019 austral summer. We describe the subsurface physical oceanography in 2019 and present the hydrographic changes between 1996 and 2019 not documented in previous studies. The survey captured decadal changes in the ocean structure from the southern flank of the Antarctic Circumpolar Current (ACC) to continental shelves. In five cross-slope meridional sections, where 1996 and 2019 measurements are comparable (112, 120, 128, 140, and 150°E), the poleward shift of the southern boundary of the ACC (50–120 km) prevailed near the continental rise. The simultaneous displacement of barotropic ACC fronts and poleward migration of deep water have contributed to full-depth warming (0.1–1.6 °C) and a reduction in the bottom water volume. Freshening was widely observed from the deep to bottom layers (~ 0.02 g/kg), whose signal extended from the upper continental slope. Bottom-intensified freshening was accompanied by oxygenation of 10–20 µmol/kg, indicating that freshening-driven oxygenation of the bottom water counteracted the deoxygenation effect of the barotropic frontal shift. Westward transport of the Antarctic Slope Current decreased by > 10 Sv from 1996 to 2019 in the five cross-slope sections; its frontal features and current axis shifted offshore by > 20 km from 112–140°E. Additionally, subsurface warming along modified Circumpolar Deep Water by up to 0.4 °C was commonly detected across the upper continental slope.

For the 2019 hydrography, shelf water sufficiently dense to form bottom water (> 28.35 kg/m3) was found to the east of Mertz Polynya (142–148°E); however, climatological sea ice production eastward to the Ross Sea was not significant, implying a pathway for dense shelf water export from the Mertz Polynya from its eastern margin. Our findings underscore the importance of sustained efforts for in-situ observations widely covering the East Antarctic margin.

Diapycnal and isopycnal mixing along the continental rise in the Australian–Antarctic Basin

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Data from Kaiyo-maru 2018/19 cruise were used to estimate both diapycnal and isopycnal diffusivities along the climatological positions of the Southern Antarctic Circumpolar Current (ACC) Front and the Southern Boundary between 120°E and 150°E. Diapycnal diffusivities at Upper Circumpolar Deep Water (UCDW), Lower Circumpolar Deep Water (LCDW), and Antarctic Bottom Water (AABW) densities were estimated at (9.5 ± 6.8) × 10^{-5}, (10.7 ± 2.6) × 10^{-5}, and (13.8 ± 3.7) × 10^{-5} m^2/s respectively. Using the water mass transformation framework, where a steady balance amongst advection, diapycnal and isopycnal diffusions are assumed, the isopycnal diffusivities were estimated from the diapycnal diffusivities. A box inverse model was used to estimate advection. The isopycnal diffusivities at UCDW, LCDW, and AABW densities were -30 ± 116, 16 ± 319, and -30 ± 83 m^2/s, respectively. These diffusivities were likely underestimates by 10 to 20 m^2/s because eddy transport could not be considered in the climatological data. Both diapycnal and isopycnal diffusivities were smaller than those in the ACC.

Seasonal overview of oceanography and AABW formation in the Cape Darnley region, Antarctica

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Antarctic bottom water (AABW) is crucial for regulating global climate. It currently forms in four locations around Antarctica, the Weddell sea, the Ross sea, the Mertz and Cape Darnley (~67.5-69°E, ~66.5°S), most recently discovered in 2013. The Cape Darnley polynya has the second highest sea ice production in Antarctica, which has been discerned as the main contributor to DSW and AABW formation in the region. The DSW/AABW formed here is among the densest shelf water in Antarctica, with salinity recorded at >34.8. The DSW then flows down two canyons to form Cape Darnley Bottom Water, contributing to approximately 6-13% of total AABW.

To improve our understanding of the Cape Darnley region, conductivity, temperature, and pressure data from marine mammals (seals) have been analysed. This data allows the opportunity to complete a full seasonal analysis in the polar region, despite the presence of sea ice.

I will be presenting an overview of how DSW/AABW formation has changed over the 2011-2019 period, and how it varies seasonally. Overall, there is a lack of linear trends in salinity or temperature over the decade, with the exception of increasing temperatures observed in summer. Instead, most of the interannual variability is likely driven by the changes in teleconnections and local climatic conditions from year to year with a strong seasonal signal.

Our study describes, for the first time, high temporal resolution on a decade long timescale within the Cape Darnley polynya, providing an interannual and seasonal analysis that has not been conducted before. This improved understanding of the characteristics of the water masses and especially the DSW from the Cape Darnley polynya will help to understand the formation of AABW in this region. This information will be used in future to conduct a series of simple schematic models that identify tipping points for AABW formation. These results can be used to identify other possible regions that contribute to AABW in the past, present or future, and how critical tipping points may impact its formation under our changing climate.

Tracing Antarctic freshwater from the grounding zone to the ice front in the Ross Embayment

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Results from nearly 20 years of satellite altimetry, spanning the Ice, Cloud, and land Elevation Satellite (ICESat), CryoSat-2, and ICESat-2 missions, have demonstrated that a dynamic hydrologic environment exists beneath fast-flowing portions of the Antarctic ice sheet. These subglacial meltwater systems vary on timescales of months to centuries and export freshwater from the continental interior to the global ocean through an interconnected network of subglacial streams, rivers, and lakes, then across the grounding zone, where the ice sheet transitions to floating ice shelves. Freshwater export from the subglacial system modifies ice-ocean processes both locally at the outflow point, as a result of meltwater forming buoyant plumes that drive increased grounding zone and sub-ice-shelf melt, and regionally, due to circulation modification in sub-ice-shelf cavities and beyond ice-shelf fronts. Although the importance of freshwater export across the grounding zone, through the sub-ice-shelf cavity, and into the open Southern Ocean has been recognized for decades, the impacts of realistic time- and space-varying freshwater inputs into sub-ice-shelf cavities have not been fully quantified due to the difficulty of observing water systems beneath 10s to 1000s of meters of ice. Here, we adapt a coupled ocean/ice-shelf/sea ice model to include time- and space-varying freshwater input into sub-ice-shelf cavities. We implement the model in the Ross Sea with observations from active subglacial lakes on the Siple Coast and demonstrate the near- and far-field impact of dynamic subglacial water systems on sub-ice-shelf circulation, basal melt, and micronutrient export.

New insights and cross-disciplinary observing requirements for (circum-) Antarctic sea-ice processes

Remotely-sensing the wave-affected Antarctic marginal ice zone using pulse-limited radar altimeters

Dr Alexander Fraser[1], Dr Zhaohui Wang[1], Dr Lisa Craw[1], Prof Takenobu Toyota[2], Ms Jill Brouwer[3], Mr Sean Chua[3,1], Dr Chris Horvat[4], Dr Petra Heil[3,1], Prof Richard Coleman[5]

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The wave-affected marginal ice zone (MIZ), a zone hundreds of km wide lying between consolidated pack ice and the open ocean, has been implicated as both a region of crucial ocean-sea ice-atmosphere interaction and a major missing process in coupled ocean-sea ice models. Our ability to understand the roles of the Antarctic MIZ in the climate system is currently limited by a lack of large-scale, reliable and historical observations of waves propagating through sea ice, and the associated rate of wave attenuation. Although recent work has shown breakthroughs in large-scale MIZ remote sensing from spaceborne laser altimetry, laser-based techniques are at the mercy of a notoriously cloudy Southern Ocean. Reliable radar altimeter-based studies of waves propagating through sea ice, which are indifferent to cloud cover, have been demonstrated as far back as 1984, but these techniques have not been carried forward to more recent (and capable) radar altimeters. Here we present first results of using the modern pulse-limited radar altimeter AltiKa for the purposes of retrieving both significant wave height and MIZ extent in Antarctic sea ice. We show that both wave height and MIZ extent can be retrieved in an automated fashion using a new, simple waveform retracker algorithm focusing solely on retrieving these quantities, and discuss validation to support this assertion. This work indicates the suitability of pulse-limited radar altimeters for MIZ property retrieval back to 2013 using AltiKa, and ultimately back to the late 1970s using other pulse-limited radar platforms, potentially providing critical information for understanding of the Antarctic MIZ.

Wave-Affected Marginal Ice Zones in Southern Ocean from Satellite Altimeters – A Study of the Indian Sector in July, 2017

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Marginal Ice Zone (MIZ) is an integral part of the Antarctic sea ice cover and usually associated with intensive air-ice-ocean interactions. Wave-affected MIZs form due to the wind wave/swell propagation into the ice pack, the ice breaking, the pronounced ocean mixing, as well as the potential positive feedback to the sea ice cover. However, great challenges exist for the satellite-based observations of the MIZ, mainly due to its small temporal and spatial scales. In this talk we introduce recent advances of observing MIZs with radar altimeters. Circumpolar remote sensing of Antarctic MIZs is carried out through the synergy of multiple satellite campaigns, with July of 2017 as the period of study. In-situ measurements within/near the Indian sector of the Southern Ocean is utilized for validation, with our retrieval results examined in detail. We show that, the wave-affected MIZ can be effectively retrieved with radar altimeters, and the synergy of multiple campaigns greatly improves the temporal and spatial representation of the underlying MIZ. Hot-spots of MIZs are revealed around the Antarctic, especially around Ross/Amundsen Sea and Weddell/Riiser-Larsen Sea. Related topics, including the swell attenuation in the MIZ, are also discussed.

Waves and sea-ice in the Marginal Ice Zone: from observations to model

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The Marginal Ice Zone (MIZ), the transitional region between the open water and ice, is the region with the largest ocean-atmosphere-ice feedbacks, making it an important dynamic region within the air-sea-ice coupled system. Due to their capacity to break the ice quickly and across large spatial domains, waves are critical in MIZ dynamics and a thorough understanding of wave-ice interactions is thus required to understand the dynamics and improve modelling accuracy of the air-sea-ice coupled system overall. In order to improve our understanding and forecasting skills of waves and sea ice in the Antarctic Marginal Ice Zone, wave-ice interactions need to be studied concurrently from both an observational and modelling perspective. We performed multiple experimental campaigns on sea ice to measure waves and estimate sea ice properties. Observations are used to characterize the processes of wave attenuation, wave dispersion and wave-induced sea ice break-up. Observational results suggest that wave and ice interactions can be captured by a binary-response model, where the continuity of the ice, that is, whether the ice is broken or unbroken, defines the type and magnitude of interaction between the waves and the ice. This is supported by our modelling efforts of coupling the waves with the ocean and the ice.

A novel system for quantitative sampling of sub-ice platelet layers

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Near the front of large ice shelves, outflowing seawater containing meltwater from deep beneath the ice shelf can become 'supercooled'. This supports the development of 'sub-ice platelet layers' (SIPLs) – accumulations of ice discs, each 2-5 mm thick, that buoyantly rise through the water column until they come to rest against the base of the sea ice. The discs coalesce to form an intricate 3-dimensional ice matrix that may extend several metres into the upper ocean. The result is a quiescent and protective marine habitat that harbours some of the highest concentrations of primary productivity associated with sea ice, but whose viability may be threatened by subtle climate shifts.

In-situ, the 3-dimensional SIPL structure can be reasonably robust. However, when samples of the SIPL are extracted the structure becomes very delicate and may disintegrate rapidly. Hence, until very recently, qualitative analysis of the integrated SIPL system – comprising the ice structure itself, the interstitial fluid, and any associated biology – has not been possible.

Here we describe the development, testing, and initial deployment of a new, bespoke-engineered system for coring SIPLs. The system sequentially extracts segments of the SIPL without destroying the structure or disassociating the ice from the interstitial fluid or incorporated biology. The samples can then be analysed for ice/water fraction, physical characteristics, or biological assemblage, each of which can be related to the environmental setting. Ultimately, the system will be used to inform assessment of the Ross Sea ecosystem's susceptibility to change as determined by the vulnerability of the unique SIPL habitat.

Using historical data compilations and novel methods to improve observational coverage of Southern Ocean sea-ice biogeochemical properties

Dr Klaus Meiners[1,2,3]

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Sea ice is a key driver of Southern Ocean biogeochemical cycles and a structuring element in Antarctic marine ecosystems. Due to its snow cover and highly reflective properties, sea ice chemical and biological properties can not be observed on large scales, e.g. remain invisible to currently available airborne or satellite remote sensing techniques. Ongoing international efforts (e.g., as part of the Biogeochemical Exchange Processes at Sea-Ice Interfaces "BEPSII" initiative) have established data compilations for a variety of biogeochemical parameters including chlorophyll a, macro-nutrients, iron and organic carbon. In parallel, novel optical methods have been developed to measure ice-core photo-pigment content from transmitted under-ice irradiance spectra, allowing ice algal biomass estimates from moored and moving under-ice platforms. This talk will explore the suitability of these two different data sources (historical data versus novel methods) to improve Antarctic sea-ice zone process understanding, and to evaluate sea ice biogeochemical models. The presentation will also highlight the remaining critical regional-scale observational gaps and discuss potential pathways to close them, e.g., by using ship-based and longer-term ice-tethered sea-ice observing systems that are currently being developed.

An international circumpolar compilation of macronutrient concentrations in Antarctic land-fast sea ice: science highlights and open access data

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Antarctic sea ice plays an important role in Southern Ocean biogeochemistry and mediating Earth's climate system. Yet our understanding of biogeochemical cycling in sea ice is limited by the availability of relevant data over sufficient temporal and spatial scales. Here we present a new publicly available compilation of macronutrient concentrations from Antarctic land-fast sea ice, covering the full seasonal cycle using datasets from around Antarctica, as well as a smaller dataset of macronutrient concentrations in adjacent seawater. Such datasets can contribute to the mission of the Southern Ocean Observing System by aligning with the FAIR data principles and being represented alongside other relevant data in the SOOSmap data portal. In this talk, we will discuss the main conclusions of our analysis of the international dataset and how our compilation – and other similar data compilation exercises – can contribute to our knowledge of Southern Ocean processes and change and the inclusivity of Southern Ocean research.

Our data show a strong seasonal cycle in fast-ice nutrient dynamics whereby nutrient concentrations are high during autumn and winter, due to supply from underlying surface waters, and then are utilised in spring and summer by mixed ice algal communities consisting of diatoms and non-siliceous species. Remineralisation of organic matter and

nutrient recycling drives substantial accumulations of inorganic nitrogen, phosphate and to a lesser extent silicic acid in some ice cores during spring and summer to concentrations far in excess of those in surface waters. We will also discuss the supply of nutrients to fast ice by a number of processes and compare nutrient concentrations between our fast-ice dataset and a previous compilation of nutrient data from Antarctic pack ice. By opening up all data sources and building up a number of interlinked compilations of Antarctic sea-ice biogeochemistry data, we have the opportunity to drive a rapid acceleration in Southern Ocean science and foster increased inclusivity across the global Southern Ocean community.

Is marginal sea ice a source of Fe and impacts productivity in South Atlantic?

Dr Saumik Samanta[1], Ms Kayla Buchanan[1], **Prof Alakendra Roychoudhury**[1]

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It has been hypothesized that iron is concentrated in seasonal sea ice during Southern Ocean winter reset and is released on melting during spring and summer promoting phytoplankton blooms. The region encompassing marginal ice zone is sensitive to climate change as Southern Ocean continues to absorb more heat. To assess the significance of this understudied iron reservoir to HNLC regions, we measured the dissolved Fe (dFe) concentrations of the marginal sea ice (MIZ), overlying snow, and underlying seawater for winter and spring between 2019 and 2022. Compared to the previously published dFe data of Southern Ocean marginal sea ice[1], compacted sea ice samples (height: 60-120 cm) from the South Atlantic (between 57° and 60° S) show low dFe concentrations, ranging from below detection (limit of detection: 0.08) to 0.86 nmol kg⁻¹. The average dFe of the sea ice (0.30±0.23 nmol kg⁻¹; n=14) was comparable to the concentrations observed in the surface mixed layer (SML) south of the Antarctic Polar front (dFe_{spring}: 0.31±0.18, n=49; dFe_{winter}: 0.14±0.05, n=19). The overlying snow layer (height 15-30 cm) however shows elevated dFe concentrations as high as 3.17 nmol kg⁻¹. The dFe in the snow layer decreased from the surface to consolidated ice interface; however, an atmospheric Fe flux to the region is unlikely to minimal. The decrease did follow an increase in brine volume though. In seawaters below the consolidated ice (dFe_{winter}: 0.35±0.13, n=27) and at the melting ice edge (dFe_{winter}: 0.28±0.17, n=12), the dFe concentrations were similar during spring, but the bloom (Chlorophyll a: 1.00-3.98 mg m⁻³) was only observed in spring at the melting ice edge while below pack ice the productivity was limited (Chlorophyll a: 0.01-0.44 mg m⁻³). We propose that iron from ice may be a factor in northward lateral supply, but light penetration and local hydrodynamics may be controlling the spring blooms.

[1]Lannuzel D. et al., 2016. Elementa: Sci. Anthro. doi: 10.12952/journal.elementa.000130

Seasonal cycling of Fe in the marginal ice zone of Southern Ocean around zero meridian: linkage to phytoplankton bloom

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As part of a multi-nation, multidisciplinary study (Southern Ocean Seasonal Experiment) two cruises were undertaken in the winter and spring of 2019 along the Good-Hope line from Cape Town to the Southern Ocean. We focused on the distribution and speciation of Fe in different reservoirs south of the Antarctic polar front. Unlike the proposed seasonal variability of Southern Ocean Fe cycling, i.e., the decreasing Fe inventory in the surface mixed layer (SML) from winter to spring[1], this study shows higher dissolved Fe (dFe) stock in spring (21.1±13.9 µmol m^{-2}, CTD stations=8) than in winter (13.3±6.0 µmol m^{-2}, CTD stations=4). It is suspected that the high dissolved iron (dFe) in spring was supporting the observed phytoplankton blooms in surface water, which extended latitudinally, from the edge of marginal ice (56.25°S) to 54.66°S (Chlorophyll a: 1.33-2.57 mg m^{-3}); and longitudinally, from 0° to 8.21°E (Chlorophyll a: 1.00-3.98 mg m^{-3}). Samples collected along the ice edge between 0° and 25°E show higher dFe (0.38±0.25 nmol kg^{-1}, n=8) but lower apparent oxygen utilization (37±2 µmol L^{-1}) in SML compared to the other stations. This may suggest that dFe is being supplied by a source other than internal cycling. We propose the melting of ice as the source, which is able to stimulate phytoplankton blooms in the otherwise Fe-depleted Southern Ocean. This is further supported by an abrupt change in salinity (from 34.155±0.018 to 33.939±0.004) at the ice edge between 56° and 54°S, which is consistent with an increase in dFe from 0.19±0.08 to 0.31±0.30 nmol kg^{-1}. The results from this study point to a significant Fe reservoir in dynamic sea ice that could initiate blooms in known iron-limited waters of the Southern Ocean. The results

have important implications for our understanding of CO_2 drawdown in the changing Southern Ocean where considerable heat has been absorbed in the past decade.

[1]Tagliabue, A., Sallée, JB., Bowie, A. et al. Nature Geosci 7, 314–320 (2014)

Regional ocean observing and modelling system developments in the Ross Sea sector - Part 1

A Conceptual Model for a U.S. Ross Sea Internationally Coordinated Research Network

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The Ross Sea Region Marine Protected Area (RSRMPA) encompasses one of the healthiest marine ecosystems remaining on this planet, but one that is under increasing alteration from ongoing climate change and fishing pressure. The RSRMPA is also among the world's largest MPAs, and the biggest and most comprehensive in multi-national waters. A U.S. Ross Sea Planning Meeting was held in October 2022 to discuss current research gaps, refine existing questions, and to brainstorm on how to create an innovative and sustainable research program aimed at better understanding, conserving, and managing the RSRMPA. Here we summarize our outcomes from the Ross Sea Planning Meeting as well as our current and proposed future activities. The Planning Meeting focused on three complementary research tracks that together would build a sustainable research program in the Ross Sea. Those three research tracks were broadly (1) observations and ecosystem process studies, (2) data and model synthesis to improve our system-level understanding of the Ross Sea system, from its sensitivity to climate change and fisheries impacts to food web interactions, vulnerability and resiliency, and (3) data science and cyberinfrastructure to create data standards, integration and workflows for continuous tracking of data and updating predictions about the future ecosystem state. The development of a Research Coordination Network (RCN)

was seen as the first critical step to kick start and facilitate coordination between the proposed research tracks and with international communities. Public and policy engagement was also seen as a critical piece that spans all research tracks and networks. The planning meeting closed with the development of a conceptual framework and the identification of themes proposed for an RCN proposal (to be submitted to the U.S. National Science Foundation). Lastly, we developed strategies for networking with the wider international Ross Sea research community.

Connection of Dense Shelf Water Variability in the Western Ross Sea to the Southern Annular Mode

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Antarctic Bottom Water (AABW), which supplies the lower limb of the global thermohaline circulation, originates from dense shelf water (DSW) formed in Antarctic polynyas. Polynyas are opened by strong offshore wind from the Antarctica continent, driving offshore sea ice motion and low ice concentrations. The direct contact of the ocean with cold air results in intense sea ice production and brine rejection in the polynyas, forming saline DSW via strong ocean convection. The temporal variations of DSW production in Antarctic polynyas is important for modulating AABW variability, but the controlling climate drivers of DSW formation is not yet fully understood. In this study, combining satellite products, mooring observations and numerical simulations from a coupled ocean-sea ice-ice shelf model, we investigated and revealed the connections between sea ice production and DSW formation in the Terra Nova Bay polynyas (TNBP) of the Ross Sea with the dominant mode of southern hemisphere extratropical climate variability - the Southern Annular Mode (SAM). The potential influence of SAM variations on the bottom water properties in the slope region of the western Ross Sea were also examined. The results are important to help understand the potential interplay between changes in climate modes across the southern hemisphere extratropical regions, and future variations in DSW and AABW.

Heat and water masses distribution in the Ross Sea from observations and model simulations

Denise Fernandez[1], Craig Stevens[1,2], Melissa Bowen[2], Craig Stewart[1]

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The regional oceanography of the Ross Sea Antarctic embayment is, in relation with other circumpolar regions, one of the best-sampled in terms of high-quality hydrography. However, the observations are sparse near the continental shelf, particularly over the water mass formation regions that are likely to have the most significant trends in temperature and salinity, therefore the variability in the density field leading to changing flows is yet full of unknowns. In addition, the in situ shipboard observations have a seasonal bias because accessibility to the region is challenging during the Austral Winter. Autonomous profiling floats provide an extension of all-year-round upper ocean measurements. With increasing float availability and high-resolution model simulations and evolved state estimates in the Ross Sea there is now an opportunity to investigate the heat pathways and trends in fundamental physical parameters and to discuss future planning of a Ross Sea Observatory. Coordinated efforts with our colleagues are key for the success of the Observatory in all its phases of development.

The salinity budget of the Ross Sea continental shelf, Antarctica

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The trend and variability in the bottom water salinity in the Ross Sea is of regional and global significance. In this study we focus on the seasonality of the salinity budget over the Ross Sea continental shelf using a new coupled regional ocean-sea ice-ice shelf model. Owing to the sea ice production, the upstream advection, and the glacial melting, the Ross Sea continental shelf is characterized by the relatively saltier water on the western shelf than on the eastern shelf, with the saltiest water in the Terra Nova Bay Polynya. During the early freezing season (March-April), there is remarkable sea ice production over the broad continental shelf, which makes a significant contribution to the production of High Salinity Shelf Water (HSSW). Furthermore, the brine rejection in the polynyas leads to the salinification and deepening of the mixed layer, yet the upstream advection acts to decrease the salinity below the mixed layer until the deep convection is fully developed throughout the water column. As the contribution of Ross Ice Shelf melting to the continental shelf salinity budget is relatively small, the seasonal cycle is largely determined by the formation and melting of sea ice, the intrusion of modified Circumpolar Deep Water, and the outflow of HSSW.

The Terra Nova Bay Polynya activity in the new coupled model Polar-SKRIPSv1

Dr Alena Malyarenko[1,2], Dr Alexandra Gossart[2], A Prof Yoshihiro Nakayama[3], Prof Craig Stevens[1,4]

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The polynyas are the ice factories found around the Antarctic coast, responsible for heat and mass exchange between the atmosphere and the ocean. The sea ice production of the Terra Nova Bay Polynya, which grows only to about 3000 km2, is responsible for up to 10% of total Antarctic Bottom formation in the Southern Ocean. The dense water, formed in the Terra Nova Bay Polynya, flows northwards and has been observed to outflow from the Ross Sea with a tidal signal.

We have developed the first fully coupled regional model Polar-SKRIPSv1 for the Ross Sea. We use the Polar-SKRIPSv1 as published in Malyarenko et al. (2022). This coupled model uses the MITgcm model of the ocean, and the Polar version of the Weather and the Weather Research and Forecasting Model (PWRF). Our model is unique in conserving energy and can operate at the regional scale, making it the best tool to study mesoscale processes in the Ross Sea and make predictions on how variability of local wind jets above the continental shelf can impact the salinity and temperature of the ocean, and thus global thermohaline circulation.

In this presentation we show a case study for 2017. We focus on the sea ice production, heat and mass fluxes in the Terra Nova Bay Polynya, and show how the polynya activity depends on the poorly constrained parameters, such as drag coefficient between air and ice, and ice and water.

Controls of topographic Rossby wave properties and downslope transport in dense overflows

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Antarctic Bottom Water is primarily formed via overflows of dense shelf water (DSW) around the Antarctic continental margins. The dynamics of these overflows therefore influence the global abyssal stratification and circulation. Previous studies indicate that dense overflows can be unstable, energizing Topographic Rossby Waves (TRW) over the continental slope. However, it remains unclear how the wavelength and frequency of the TRWs are related to the properties of the overflowing DSW and other environmental conditions, and how the TRW properties influence the downslope transport of DSW. This study uses idealized high-resolution numerical simulations to investigate the dynamics of overflow-forced TRWs and the associated downslope transport of DSW. It is shown that the propagation of TRWs is constrained by the geostrophic along-slope flow speed of the DSW and by the dynamics of linear plane waves, allowing the wavelength and frequency of the waves to be predicted a priori. The rate of downslope DSW transport depends non-monotonically on the slope steepness: steep slopes approximately suppress TRW formation, resulting in steady, frictionally-dominated DSW descent. For slopes of intermediate steepness, the overflow becomes unstable and generates TRWs, accompanied by interfacial form stresses that drive DSW downslope relatively rapidly. For gentle slopes, the TRWs lead to the formation of coherent eddies that inhibit downslope DSW transport. These findings may explain the variable properties of TRWs observed in oceanic overflows, and imply that the rate at which DSW descends to the abyssal ocean depends sensitively on the manifestation of TRWs and/or nonlinear eddies over the continental slope.

Observing ice shelf ocean cavity hydrography: The Ross Ice Shelf

Prof Craig Stevens[1,5], Dr Craig Stewart[1], Ms Yingpu (Rin) Xiahou[5], Dr Natalie Robinson[1], Ass. Prof. Huw Horgan[2,6], Prof. Britney Schmidt[3], Prof Christina Hulbe[4]

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The ocean cavities beneath Antarctic ice shelves are amongst the least sampled components of the Southern Ocean system. The ice-ocean interaction in these cavities underpins processes such as ice sheet-associated sea level rise as well as sea ice production and ocean stratification in the Antarctic coastal seas. The lack of observations in these systems and the focus on specific research themes has resulted in our understanding of these systems being led by modelling informed by remote sensing and surface acquired data. Here we describe a sequence of hydrographic observations through ice shelf boreholes on the Ross Ice Shelf and how these southernmost data can contribute to the Southern Ocean Observing System. Themes emerge such as tidally-induced mixing, baroclinicity and the heterogeneity of the so called basal boundary layer.

Phytoplankton seasonal cycle and carbon export in the Ross Sea: A modeling study

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A previous modeling study that used a one-dimensional biogeochemical model implemented for the Ross Sea showed that the temporal progression of blooms of the haptophyte Phaeocystis antarctica and diatoms is sustained by dissolved iron (dFe) supplied by sea ice, benthic and Circumpolar Deep Water sources, and light availability, which is moderated by sea ice. This modeling study extends the one-dimensional biogeochemical model to the Ross Sea shelf. The biogeochemical model is embedded in a three-dimensional coupled circulation-sea ice-ice sheet model implemented for the Ross Sea. The expanded model allows simulation of the space and time progression of P. antarctica and diatom blooms and identification of the processes that govern these blooms. Initial simulations consider the effect of opening of the polynya and winter recharge of surface dFe concentrations on spring phytoplankton blooms. Preliminary results suggest the opening of the polynya enables early availability of light, which coupled with enhanced dFe concentrations, favors P. antarctica dominated blooms in the spring. Simulated bloom progression along across-shelf transects shows the relative importance of dFe and light availability in controlling the phytoplankton assemblage in the western and eastern Ross Sea, with implications for patterns of primary production in different regions of the Ross Sea. The simulation results point to data that are needed to support implementation of coupled circulation-biogeochemical models for the Ross Sea.

Distributed research efforts from the Scotia Arc through the West Antarctic shelf seas

Atmospheric forcing of interannual variability in Amundsen Sea basal melt rates

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Basal melting at the subsurface is responsible for a large amount of mass loss of the Antarctic Ice Sheet, with the largest melt rates occurring in West Antarctica. A key area for this is the Amundsen Sea where relatively warm Circumpolar Deep Water has direct access to the continental shelf and the ice shelf cavities resulting in large melt rates at depth. Several previous studies emphasize the link between atmospheric conditions, the inflow of warm water on to the continental shelf via deep troughs in the shelf break and basal melt rates. In this study, using an eddy-resolving ocean model, ACCESS-OM2-01, we investigate what drives the interannual to decadal variability of basal melt rates in the Amundsen Sea. We find a high correlation (r>0.85) between observational estimates of Amundsen basal melt rates (1992-2017) with ocean model simulations of local shelf temperature.

Our results suggest that while the inflow of Circumpolar Deep Water on the continental shelf is very important in the mean state its role in interannual variability is limited. Instead, a local heaving of the thermocline lifts warmer water from depth which results in a localized warming at mid-depths directly at the ice shelf front. This process is modulated by the Antarctic coastal current which brings meltwater from the Bellinghausen Sea into the Amundsen Sea. A weaker coastal current and hence less import of cold and fresh water from the East leads to warmer conditions at the ice shelf front and therefore higher melt rates. These ocean processes are driven by local wind stress. Our results indicate that the role of intrinsic ocean variability is limited in this process and most of the variability in the temperatures at the ice shelf front is controlled by the atmosphere. This indicates a potential of predictability for future ocean temperatures and hence basal melt rates in the Amundsen Sea based on future winds which are projected to weaken over the continental shelf in a warming climate. By applying idealized atmospheric perturbation experiments we aim to further investigate the ocean response to future local wind changes and the robustness of simple melt rate predictions.

Ecological Response to "Press-Pulse" Disturbances Along a Rapidly Changing West Antarctic Peninsula

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Seasonal sea ice-influenced marine ecosystems at both poles are characterized by high productivity concentrated in space and time by local, regional, and remote physical forcing. These polar ecosystems are among the most rapidly changing on Earth. The PALmer (PAL) LTER has for three decades focused on understanding the western side of the Antarctic Peninsula (WAP) to gain new mechanistic and predictive understanding of ecosystem changes in response to disturbances spanning long-term, subdecadal, and higher-frequency "pulses" driven by a range of processes, including long-term climate warming, natural climate variability, and storms. These disturbances alter food-web composition and ecological interactions across time and space scales that are not well understood. Three multidisciplinary, interrelated research themes guide our work: A. Drivers of disturbance across time/space scales: ecological and latitudinal response, B. Vertical and alongshore connectivity as drivers of ecological change on local to regional scales, C. Changing food webs and carbon cycling. The WAP has changed significantly over at least the last fifty years with change projected into the future. The most rapid sea ice decreases in Antarctica have occurred along the WAP and Bellingshausen Sea. Seasonal sea-ice changes in the WAP are largely wind driven forced by tropical Pacific and Atlantic Ocean teleconnections and the Southern Annular Mode (SAM). While the number of sea-ice days per year has consistently been declining since the late 1970s, a reversal started in 2010 and terminated in 2017. In the southern region of the PAL sampling grid, the summer upper-ocean mixed layer depth has shallowed by a factor of two over the last 20 years, with long-term observations showing concomitant increases in phytoplankton biomass. Biomass increases are positively correlated with phytoplankton species richness and evenness, driven by high diatom diversity. Increased phytoplankton biomass is consistent with observations/experiments suggesting continental shelf seasonal primary productivity is light-limited, which is alleviated with a shallower seasonal MLD. The recent sea ice reversal resulted in increased annual phytoplankton biomass north of Palmer station, reversing long-term phytoplankton declines. The keystone species Antarctic krill (Euphausia superba) to date has no significant long-term directional change in the PAL study region, although populations farther north have decreased. Other key macrozooplankton taxa show both increasing and decreasing trends in abundance, and some–such as ice krill (E. crystallorophias), salps, and pteropods–are correlated with ENSO or SAM climate cycles. Climate also is driving long-term change in Antarctic Silverfish (Pleuragramma antarctica) larvae, with warmer sea surface temperature and decreased sea ice associated with reduced larval abundance. We will review these changes and relate them to the observed changes in the higher trophic levels.

FjordPhyto, a citizen science platform that enhances spatial and temporal coverage of nearshore phytoplankton research on the Antarctic Peninsula

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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. The resulting influx of glacial meltwater to the coastal ecosystems may influence the composition and dynamics of primary producers. It is critical to document these changes, gathering time-series data throughout the seasonal growth period, because any shifts in the phytoplankton community can affect higher trophic level organisms in the nearshore food web. The Antarctic tourism industry maintains a fleet of vessels that visit the Peninsula's nearshore waters throughout the austral summer, from November to March, regulated by the International Association of Antarctica Tour Operators (IAATO). We developed a Citizen Science (CS) program— FjordPhyto—to leverage these vessels as platforms of opportunity for gathering data about the region. This program enables a larger spatial and temporal scale to be sampled in the surface nearshore waters of the Antarctic Peninsula. Expedition staff are trained by FjordPhyto researchers and facilitate participation by travelers on board tour ships. Participants collect environmental data and biological samples that are sent to researchers for analysis at the end of each austral summer. Data collection from multiple sites includes phytoplankton species identification; cell counts and carbon biomass estimates by microscopy; euphotic depth measurements; ocean color; CTD salinity, temperature, and Chlorophyll-a profiles to 100m; plankton metabarcoding and metatranscriptomics; and oxygen isotope meltwater content. Over 43 unique locations since 2016 to date were sampled, with specific popular sites visited 15 times a season (nearly every week), to build a time series of regular sampling occurrences over a wide area (approximately between 62° and 68°S). The project aims to create a seasonal progression of the phytoplankton community and understand interannual variability related to freshwater influence from melting glaciers in nearshore areas of the Antarctic Peninsula. These in-field efforts to collect surface ocean measurements also aid in ground-truthing satellite remote-sensing products as well as developing predictive algorithms models. The FjordPhyto project shows 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.

Small scale bottom up controls of foraging behavior in a biological hotspot

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Although krill aggregations occur throughout the Western Antarctic Peninsula, the distribution of penguin populations and their associated foraging areas are spatially coherent with canyons and nearshore deep bathymetry. These areas are characterized by elevated biomass, and labeled biological hotspots. Within these hotspots, penguin foraging locations may be highly variable in accordance with the small-scale patchy distribution of their prey. The short and spatially varying surface residence time relative to longer phytoplankton doubling times and the foraging behavior of local penguin species raises important questions about the physical mechanisms sustaining the food web in these biological hotspots. To better understand the physical biological coupling that sustains this hotpot, we deployed a polar ocean observatory, purpose-built to resolve the necessary spatiotemporal scales of this marine ecosystem. Ocean and ecological surveys conducted with underwater gliders and small boats were conducted within the footprint of a mooring array and a three-site High Frequency radar network recently introduced to the region. This integrated ocean observing system resolved the ecological coupling from the underlying ocean dynamics up through the food web to the top predators. These data consistently highlighted the persistence of spatially varying features across the region including eddies, fronts, and jets. The spatial variability of these features is likely driven by small scale, but impactful, differences in the overlying winds and underlying ocean currents that can vary dramatically from one side of the canyon to the other. New insights provided by our observatory suggest that this spatial variability influences predator foraging behavior from one side of the canyon to the other. The close proximity of these two different foraging environments may add ecological resilience to the region with multiple physical regimes accessible within the hotspot. This is particularly important for the place-based penguin foragers that have occupied this region for millennia despite significant inter-annual and climactic scale variability.

Quantifying Physical Prey Concentrating Features in Palmer Deep, Antarctica

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Food resources in the polar ocean are relatively diffuse, and need to be concentrated for consumers. This is done, in part by mesoscale and sub mesoscale oceanographic features transporting and locally concentrating plankton, creating patchy regions of high prey availability. Lagrangian approaches applied to coastal ocean dynamics can identify the transport features responsible for plankton patchiness, linking highly nonlinear coastal flow to the spatial ecology of food webs. This study employs two Lagrangian coherent structure approaches, Finite Time Lyapunov Exponents (FTLE) and Relative Particle Density (RPD), to coastal surface currents observed by High Frequency Radars (HFR) around a known biological hotspot, Palmer Deep Antarctica. Palmer Deep's relatively short and tightly coupled food web makes it a great ecological laboratory to observe prey concentrating features. FTLE and RPD results were compared to the spatial ecology of phytoplankton, zooplankton, and foraging penguins, relating each level of the food web to lagrangian transport. Simultaneous measurements of the physics and food web were gathered through the integration of vessel and autonomous glider surveys within the HFR footprint. Results show FTLE better define plankton patches compared to RPD, and FTLE defined in stratified conditions better define plankton patches compared to mixed conditions. Further, results show that transport features quantified by FTLE deliver and concentrate supplies of plankton, maintaining prey resources relied on by local penguin colonies. This quantified relationship between ocean movement and food web dynamics can be applied to predictions of spatial ecology and changing prey conditions. Results will inform future work in the identification of biophysical interactions in more complex food webs and emphasize the role of transport in the maintenance of the biological hotspot around Palmer Deep.

Examining the Connectivity of Antarctic Krill on the West Antarctic Peninsula: Implications for Pygoscelis Penguin Biogeography and Population Dynamics

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Antarctic krill (Euphausia superba) are considered a keystone species for higher trophic level predators along the West Antarctic Peninsula (WAP) during the austral summer. The connectivity of these populations may play a critical role in predator biogeography, especially for central-place foragers such as the Pygoscelis penguins that breed along the WAP during the austral summer. Here, we used a physical ocean model to examine adult krill connectivity in this region using simulated krill with realistic diel vertical migration behaviors across four austral summers. Specifically, we examined krill connectivity around the Adélie gap, a 400 km long region along the WAP with a distinct absence of Adélie penguin colonies, to determine if krill population connectivity around this feature played a role in its persistence.

Our results indicate that krill populations north and south of the Adélie gap are nearly isolated from each other and that persistent current features play a role in this inter-region connectivity, or lack

thereof. Our results indicate that simulated krill released within the Adélie gap are quickly advected from the region, suggesting that the lack of local krill recruit retention may play a role in the persistence of this biogeographic feature.

Are biological hotspots farms or markets? The importance of resource retention for maintaining an Antarctic biological hotspot.

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Food resources in the ocean are dilute, therefore they must be concentrated for carbon to be passed up the food web. This can be accomplished through local population growth, transport, or aggregating behavior. Biological hotspots in which local growth is a dominant factor in accumulating food resources operate more like “farms”, producing food locally. In contrast, biological hotspots in which Lagrangian transport, advection and retention are dominant factors operate more like “markets”, concentrating food resources produced in other regions. Here, we show that in Palmer Deep Canyon, a biological hotspot in the West Antarctic Peninsula likely operates like a market as opposed to a farm. This hotspot contains a bathymetrically driven sub-surface eddy that retains biogenic particles below the mixed layer, a potential food source for grazers. In simulations, this eddy also traps diel vertically migrating zooplankton, keeping them retained in the region, and within close foraging distance from regional penguin colonies. Simulations further show that in the absence of this eddy, krill delivery rates to penguin foraging areas are significantly reduced, showing the importance of the retention of food resources to the local ecology. Regions that have the ability to attract and concentrate food resources may serve as refuges in a rapidly changing climate.

Southern Ocean sea ice variability in a warming climate: observations and modeling approach – Part 2

Does the recent decline in Antarctic sea ice indicate a climate shift? Insights from satellite observations,Argo floats, and model reanalysis

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Ever since the abrupt drop in Antarctic sea ice extent (SIE) began in spring 2016, as opposed to its consistent growth (1.95% decade-1 from 1979 to 2015), the SIE in the satellite era has reached record lows in 2017 and 2022. From spring 2016, the satellite-based SIE remained consistently lower than the long-term mean, with the trend dropping to 0.38% decade-1 from 1979 to 2022. The top record lowest SIE years were observed since 2016, corresponding to the warmest years dating back to 1979. The SIE dropped to a record low of 31% in February 2022, 13.67% in June 2022, and 23.8% below the average in December 2022. We find that the observed decline in SIE during 2016-2022 occurred due to the combined influences from the intensification of atmospheric zonal waves with enhanced poleward transport of warm-moist air and anomalous warming in the Southern Ocean. Although the sudden sea ice decline in spring 2016 occurred corresponding to the transitional climate shift from IPO- (Interdecadal Pacific Oscillation, 2000-2014) to IPO+ (2014-2016), the recent decline after 2016 occurred in a dominant IPO- and Southern Annular Mode (SAM+). Our research using various coupled model intercomparison project phase-6 models showed a consistent decrease in ensemble-mean SIE from 1979 to 2022. The model trend is similar to the recent declining trend in SIE from satellite observations since 2016, hinting towards a warmer climatic shift.

Novel model of sea ice growth to improve observing system for Antarctic polynyas

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According to recent large-scale study [1] "there are critical gaps in knowledge concerning interactions between the atmosphere and specific elements of the polar ocean … such gaps limit understanding of … the polar regions and … climate systems [1]."

The atmosphere is certainly a major driver causing evolution of sea ice in Antarctica, but the uncertainty in snow depth on ice represents a significant problem to model seasonal sea ice evolution. Gaps also remain in the current observations on the thermal atmosphere influence in offshore polynyas around Antarctica determining mass, heat and salt fluxes in the areas adjacent to ice shelf regions in winter.

New developed approach includes two principal modifications. In contrast to existing models snow depth is not considered as predetermined function of ice thickness, but depends on solid precipitation accumulation rate. Surface temperature of snow on ice is defined as internal model parameter maintaining rigorous consistency between processes of atmosphere-ice thermodynamic interaction and ice growth.

The deeper snow, the closer surface temperature to air temperature, which represents a negative feedback included in the new consistent model. The enhanced model of ice growth enables analytical solution simplifying calculations of ice thickness and related fluxes of mass, heat and salt.

Amazingly the derived solution establishes relationships only with meteorological parameters: air temperature, solid precipitation rate and wind speed. It means that the solution of a meteorological problem allows to estimate the influence of the atmosphere on the processes of convective mixing and forming deepest water masses. The Antarctic Bottom

Water propagates as far as North Atlantic presenting an important linkage in global climate change.

Developed approach can be leveraged to improve data collection and coverage for offshore polynyas and integration with oceanic studies of important ice shelf - ocean interactions processes in Antarctica. The enhanced analytical model (including critically important feedback) could be also recommended for calculations of climate change in sea ice.

The Moderate Resolution Imaging Spectroradiometer (MODIS) and Sentinel observations are applicable as a primary source of satellite data. Landsat high resolution information provides data for detailed analysis.

1. 1. M. Meredith and M. Sommerkorn, 2019. The Ocean and Cryosphere in a Changing Climate. Chapter 3, Polar Regions, IPCC Report. 203-320.

Variability and trends of the Antarctic marginal ice zone

Prof Marcello Vichi[1]

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Remote-sensing records over the last 40 years have revealed large year-to-year global and regional variability in Antarctic sea ice extent (SIE). Sea ice area and extent are useful climatic indicators of large-scale variability, but they do not allow the quantification of regions of distinct variability in sea ice concentration (SIC). This is particularly relevant in the marginal ice zone (MIZ), which is a transitional region between the open ocean and pack ice, The debate on MIZ trends in a warming climate and its relationship with SIE trends is still open for both hemispheres. The use of an alternative indicator for detecting MIZ conditions in Antarctic sea ice allows to quantify variability at the climatological scale on the ice-covered Southern Ocean over the seasons, as well as to derive maps of probability of encountering a certain degree of variability in the expected monthly SIC value. The results present a revised view of the Antarctic MIZ and SIE variability and seasonal cycle, with a rapid increase in the MIZ extent and saturation in winter, as opposed to the steady increase from summer to spring reported in the literature. It also reconciles the discordant MIZ extent estimates using the SIC threshold from different space-born algorithms. Regional trends indicate that detecting changes in such a highly variable system require longer time series, and a dedicated effort to characterize Antarctic sea ice types differently from the Arctic.

Antarctic snow depth, ice thickness and ice volume variability in the context of the 2022 and 2023 record minimum extent

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On 25 February 2022, sea ice extent in the Southern Ocean reached a record low, driven by a decrease in all sectors. In February 2023, Antarctic sea ice reached a new record with the lowest extent ever observed since the beginning of the satellite era. Changes in ice thickness and volume are essential to better understand the observed variability and links to physical drivers. Using near-coincident measurements from the ICESat-2 lidar and the CryoSat-2 radar, we examine the variability of snow depth, ice thickness and ice volume between April 2019 and September of 2022. In this analysis, we focus on the behavior of sea ice in the Weddell, Bellingshausen-Amundsen and Ross seas. Antarctic sea ice is usually the thinnest in the Ross sector, which has suffered the greatest loss in the past couple years. Observations from satellite altimeters capture a thinner sea ice cover in the Ross sector in the months preceding the 2022 and 2023 records. Satellite-derived sea ice drift reveal a coincident positive anomaly in northward ice export in the Ross Sea. We further assess the variability of mean sea level pressure, cyclone characteristics (occurrence, intensity and snowfall) and freezing degree days from ERA5 reanalysis to link the observed changes of the Antarctic sea ice cover to dynamic and thermodynamic drivers.

Regional ocean observing and modelling system developments in the Ross Sea sector Part 2

Summer physical and biogeochemical conditions in Ross Sea polynya from glider data

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Two Seagliders equipped with sensors measuring temperature, salinity, dissolved oxygen, chlorophyll and optical backscatter, were deployed in the Ross Sea between early December 2022 and late January 2023. The two gliders simultaneously sampled the Ross Sea polynya between 170-172°E and 77.4-76.4°S. We obtained nearly two months of high resolution full-depth profiles (up to 800 m depth) that allowed the detailed description of the water-mass properties in the polynya in summer. The water column consists in an surface layer of fresh (absolute salinity between 33.5 and 34 g kg-1) water that extends up to 50 m depth and captures the seasonal progressive warming and sea ice melting. Over the almost two months of sampling, the surface temperature varied between -1.8 and 0.5 °C. Then, strong temperature and salinity gradients result in a shallow mixed layer depth with local maxima of 50 m. The interior ocean exhibits conservative temperatures near the surface freezing point and absolute salinity up to 35 g kg-1. Additionally, we have information on the regional circulation from the dive averaged currents estimated from the gliders trajectories. During their journey, the gliders sampled several eddies (cyclonic and anticyclonic) as well as a phytoplankton bloom and decay. We observe that dissolved oxygen and optical backscatter are highly directly correlated to temperature. However, in the case of

the Chlorophyll this correlation varies with depth, time/location, and suggests changes in the planktonic community. In this presentation I will discuss the physical forcings behind the observed hydrographic and biogeochemical variability with particular focus on the eddy field and their role in water-mass transport.

Observing zooplankton and Antarctic silverfish in the Ross Sea

Dr Svenja Halfter[1], Dr Matt Pinkerton[1]

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Zooplankton are essential components of the Southern Ocean food web, as they connect lower trophic levels such as phytoplankton, to higher trophic levels up to fish, marine mammals, and seabirds. They also contribute to the downward carbon flux, by producing fast-sinking faecal pellets and carcasses, modifying sinking particles, and actively injecting carbon into the deep sea during their migrations. The Ross Sea is a highly productive ecosystem, yet zooplankton numbers are assumed to be comparatively low because of the decoupling of fast-growing phytoplankton from zooplankton. In addition, the pelagic community on the shelf differs significantly compared to the open Southern Ocean: the food web is based on crystal krill (Euphausia crystallorophias) and Antarctic silverfish (Pleuragramma antarctica), rather than Antarctic krill.

Here, we present the current observing system in the Ross Sea that aims to resolve zooplankton dynamics and their role in the food web and downward carbon flux. Available platforms, such as the Continuous Plankton Recorder that is towed behind ships of opportunity, and regular ship- and land-based sampling efforts will be introduced. Then, we describe zooplankton research from the recent voyages of the RV Tangaroa between 2018 and 2023. Available zooplankton data, opportunities to collaborate, and limitations of the sampling program will be explored. As an example, stable isotope and carbon standing stock data from selected meso- and macrozooplankton species, including pteropods, amphipods, krill and salps, as well as Antarctic silverfish will be compared between years to illustrate temporal and spatial variability of ocean observations. Finally, we recommend future developments in observing platforms and discuss ocean data requirements to close current knowledge gaps.

The net community production and phytoplankton community changes at the Ross Sea

Dr. Yonghui Gao[1], **Ji Li**, **Shuyi Fei**, **Michael Bender**, **Maojun Yan**

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The Ross Sea is the most productive area in the Southern Ocean. We only took 10 days to scan the Ross sea with high-resolution measurements of O2Ar and variable fluorescence in the austral summer. However, changes in the phytoplankton community and metabolism, especially in the two polynyas, exhibited large spatial variation. Phytoplankton succession was tightly linked with the ice history due to nutrient-light availability. Ice-open at Terra Nova Bay Polynya (TNBP) was earlier relatively than the Ruppert Coast Polyna (RCP). The phytoplankton communities were dominant by diatom at RCP and Phaeocystis at TNBP. The limited nutrient and low photosynthesis efficiency (FV/Fm) at TNBP indicated the late stage of bloom and thus the low net community production (NCP), the difference between gross phytoplankton production and community respiration. On the other hand, the blooming season was just started at the TNBP as the result of enough nutrients and light. Consequently, high Fv/Fm (> 0.45) and phytoplankton biomass lead to over 10 times higher NCP. Quantitative analyses show that ice history associated with biogeochemical changes governed the phytoplankton community and its contribution to carbon cycles.

Spatio-temporal variation of glacial meltwater and its influences on the continental shelf region of the Ross Sea

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Dense Shelf Water (DSW), with a temperature close to the surface freezing point ($T \sim -1.9°C$) and relatively high salinity ($S > 34.70$), is produced via the coastal polynyas of the western Ross Sea. Where DSW intrudes into the ice shelf cavities it induces basal melt. The resultant glacial meltwater is identified as Ice Shelf Water (ISW; $T < -1.9°C$, $S \sim 34.7$), but the implications of this for the Ross Sea are poorly understood due to limited observational data, especially from the austral winter. ISW has the potential to modulate water masses, influence sea ice production, and induced supercooling-affected sea ice growth. This latter point has ecosystem implications as it affects sea ice growth and sub-ice habitat. Here, we investigate the formation and fate of ISW in the Terra Nova Bay polynya region (TNBP) using ship-based and moored timeseries hydrographic data as well as data from instrumented seals. These data suggest that ISW was mainly formed via DSW incursion into the sub-shelf cavity from January and it was mainly circulating through the TNBP, McMurdo Sound, and the front of the Ross Ice Shelf. It was found that the observation depth of the ISW became shallow approximately from 400 m to 200 m between February and June, indicating that the ISW was upwelled by buoyancy gain from the continuous glacial meltwater outflow from the ice shelves. The locations where ISW was observed were consistent with the regions of high sea ice concentration, and these results show that the upwelled ISW could contribute to sea ice production. Notably, from July to December, the ISW almost disappeared over the continental shelf region of the Ross Sea. This appeared to be associated with weakening of stratification due to active DSW formation by strong wind events in the polynya that occurs near the ice shelves where the ISW mainly flows out. Furthermore, comparing the long-term change in ISW properties with hydrographic data (WOD13) observed from the mid-1990s, it suggests that the changes were closely related to the change in DSW properties. This is because the change in DSW properties determine available ocean heat content supplying into the sub-shelf cavity. This research demonstrates the clear connections between atmosphere, ocean, sea ice and ice shelves in the Ross Sea sector.

Long-term moored observations of export and exchange from the northwestern Ross Sea

Dr Melissa Bowen[1], Dr Denise Fernandez, Dr Craig Stevens, Dr Arnold Gordon, Dr Bruce Huber, Dr Pierpaolo Falco, Dr Pasquale Castagno, Dr Giorgio Budillon

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The exchange of water between the Ross Sea and the open ocean at the shelf edge is a key control on the heat, salt and nutrient budgets on the shelf and sets the flow of CDW towards the Ross Ice Shelf. The exchange also regulates the delivery of dense water to the global ocean. Due to the complex shelf bathymetry, much of the exchange appears located in the deeper troughs, providing natural monitoring points for the circulation. We review our understanding of the dense water export from the northwestern Ross Sea and our current insight into the exchange of dense water and CDW in the Drygalski Trough from the long time series of moored observations collected by three national programmes over the past two decades. We discuss key sites for monitoring these flows and thoughts on connections to other regions of the Ross Sea.

Sea Surface Height Signature of the Dense Water Overflows in the Ross Sea

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The Ross Sea is a critical dense water production region. This dense water sinks to the bottom and spills on the continental shelf into canyons, with dense water overflows occurring at the shelf break and flowing into the open ocean in the form of pulses. Being able to monitor these overflows from satellite observations would uncover the variability and the changes in the bottom water production in the Ross Sea. Here, we present a new method for understanding and observing dense dater overflows variability using sea surface height (SSH) from ACCESS-OM2 model simulations and satellite altimetry observations in the subpolar Southern Ocean.

The ACCESS-OM2 model simulations reasonably reproduces Dense water overflows in the Ross Sea, which impact local steric height and SSH. By filtering out large-scale and long-period SSH variability, we can isolate the SSH signal related to dense water overflows. The strength of this SSH signal responds accordingly to perturbations of the model that modify the rate of dense water formation, which suggest that the variability of this SSH component is related to the strength of dense water production.

Satellite altimetry along-track observations are processed using a similar filtering method to isolate dense water overflows variability. We find stronger SSH variability in the canyon regions, where overflows are expected to occur. We evaluate the interannual variability of the overflows based on six years of satellite observations.

Our results demonstrate the potential of using SSH from model simulations and satellite altimetry observations to study dense water production and its variability. This approach can improve our understanding of the processes driving bottom water production in the Ross Sea and improve our ability to monitor their variability and changes.

Observing, mapping and monitoring Antarctic, seafloor fauna and their habitat

The International Bathymetric Chart of the Southern Ocean

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International Bathymetric Chart of the Southern Ocean (IBCSO) is a regional mapping initiative of the General Bathymetric Chart of the Oceans (GEBCO) and the Nippon Foundation – GEBCO Seabed 2030 Project (Seabed 2030). It provides the most authoritative map in 500 m resolution of the Southern Ocean and the south Atlantic, south Pacific and South Indian Ocean south of 50°S.

Here we present the second version of IBCSO – IBCSO v2. The first version was released in 2013 covering the area south of 60°S. Driven by the demand from the user community and a significant increase of new data sets, IBCSO v2 was published in June 2022 containing 25 billion data points from 1500 datasets from more than 88 institutions and institutes from 22 countries.

In IBCSO v2, 23.7% of the seabed are constrained by soundings. This means that less than a quarter of seabed is actually mapped while more than three quarters are satellite derived predicted bathymetry. We would therefore like to take the opportunity to encourage people to engage with IBCSO and to contribute bathymetric data to make IBCSO v3 an even more amazing map.

Dorschel B., Hehemann L., Viquerat S., Warnke F., Dreutter S., Schulze Tenberge Y., Accettella D., An L., Barrios F., Bazhenova E., Black J., Bohoyo F., Davey C., De Santis L., Escutia Dotti C., Fremand A.C., Fretwell P.T., Gales J.A., Gao J., Gasperini L., Greenbaum J.S., Jencks J.H., Hogan K., Hong J.K., Jakobsson M., Jensen L., Kool J., Larin S., Larter R.D., Leitchenkov G., Loubrieu B., Mackay K., Mayer L., Millan R., Morlighem M., Navidad F., Nitsche F.O., Nogi Y., Pertuisot C., Post A.L., Pritchard H.D., Purser A., Rebesco M., Rignot E., Roberts J.L., Rovere M., Ryzhov I., Sauli C., Schmitt T., Silvano A., Smith J., Snaith H., Tate A.J., Tinto K.J., Vandenbossche P., Weatherall P., Wintersteller P., Yang C., Zhang T., Arndt J.E., 2022. The International Bathymetric Chart of the Southern Ocean Version 2. Scientific Data 9, 275, https://doi.org/10.1038/s41597-022-01366-7.

A circumpolar benthic bioregionalisation for the Antarctic continental shelf derived from seafloor imagery.

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Areas that contain ecologically distinct biological content, called bioregions, are a central component to understanding broad-scale biodiversity patterns and for spatial and ecosystem-based management. However, the distribution seafloor communities around Antarctica is poorly known because biological data are relatively sparse over the vast scale of the Antarctic shelf. Therefore, large scale bioregionalisations are generally produced using full coverage environmental data and are assumed to be proxies for biodiversity patterns and /or expert opinion, which is less transparent or reproducible. Here we develop a 2 km resolution, circumpolar benthic bioregionalisation that explicitly integrates biological data and uses a robust statistical framework. We utilise a new and extensive circumpolar database of 3, 500 consistently annotated seafloor images, called Antarctic Seafloor Annotated Imagery Database, coupled with environmental data in a novel statistical approach called Regions of Common Profile to delineate, describe and predict the distribution of circumpolar bioregions. In this talk we briefly outline the approach and describe the species profiles, environmental characteristics and spatial distribution of the bioregions identified. These maps have multiple potential uses. We discuss their ability to provide a useful baseline for understanding broadscale biodiversity patterns and their potential to inform survey designs for future monitoring.

The circum-Antarctic distribution of seafloor biodiversity: Identifying hotspots of seafloor biodiversity and priorities for future research cruises

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The Antarctic seafloor contains unique and highly diverse species communities. While the conservation value of Antarctic seafloor communities is well recognised, many aspects of the distribution of this biodiversity are unknown, hindering informed management and conservation. Collaborating with scientists from all over the world we've created the Antarctic Seafloor Annotated Imagery Database (AS-AID) which contains 180 morphospecies classifications across 3,599 consistently annotated images from 19 research cruises.

In this talk we will present high-resolution (2km) maps of the distribution of Antarctic seafloor biodiversity, modelled by combining joint species distribution models with AS-AID and a suite of relevant environmental predictor variables. In total, we mapped the circum-Antarctic distribution and prediction-uncertainty for 83 of these morphospecies. We will highlight biodiversity hotspots/areas of ecological significance, zoom in on select regions and highlight priority areas for monitoring and future research cruises. These circum-Antarctic maps represent a significant step-change in the type of seafloor biodiversity information available to spatial planning, conservation and policy.

Identifying Vulnerable Marine Ecosystems in the Southern Ocean: circumpolar model prediction and vulnerability index quantification

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In 2009, CCAMLR committed to avoiding adverse impacts to seafloor communities in the Southern Ocean, including those known as Vulnerable Marine Ecosystems (VMEs), which are characterised by fragile, slow growing, long-lived, and habitat-forming ‘VME indicator’ taxa. CCAMLR mainly relies on fisheries bycatch data for VME identification, applying threshold-based conservation rules in which all indicator taxa are considered equal. However, these taxa have different vulnerabilities to fishing disturbance and little consideration has been given to how these taxa may combine to form components of ecosystems with high conservation value. Besides the fishing threat, Antarctic seafloor communities are increasingly being affected by other threats induced by warming and ocean acidification components of climate change. The increasing availability of data derived from imagery provides an opportunity to consider multiple indicator taxa and assess their vulnerability to multiple threats simultaneously. We propose a multi-criteria approach to assign a vulnerability index to the predicted circumpolar distribution of taxa. We fit joint-species distribution models using the “Antarctic Seafloor Annotated Imagery Database”, where 68 VME indicator morpho-taxa have been manually annotated generating >40,000 annotations from >1,800 images, and environmental data. The models, trained on presence-absence and abundance data, were used to predict the distribution of these VME indicator morpho-taxa on the Southern Ocean continental shelf with a 2km resolution. From these predictions, two indices were computed, accounting for the total VME indicator taxon abundance and richness, respectively. In these indices, each morpho-taxon is weighted differently based on its estimated vulnerability to fishing, warming and ocean acidification. This analysis provides a circumpolar quantification of the seafloor assemblages’ vulnerability to selected multiple threats. The code and the georeferenced maps will be made publicly available. The use of this quantitative assessment of the seafloor assemblages’ vulnerability could enhance VME identification in the Southern Ocean and make risk assessment more meaningful.

The muddy road to forecast distribution patterns of polychaete communities (taxonomic and functional groups) on the Weddell Sea Shelf

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The Antarctic Peninsula (AP) and the Weddell Sea (WS) are increasingly threatened by effects of climate change. In order to establish conservation strategies and forecast benthos in the WS under the changing environmental conditions, it is essential to understand the benthic community composition and distribution and their relationships to abiotic drivers. But in regions as the Southern Ocean (SO) biological data are limited due to accessibility constrains and funding, time. Therefore, using environmental surrogates for fauna data is an attractive alternative as physical data provide a greater spatial and temporal coverage and availability. An important and dominant group in soft-bottom ecosystems are polychaetes, due to their wide diversity of functional groups. However, knowledge of their distribution patterns and ecological drivers in the SO is scarce and incomplete, despite increasing sampling efforts and research interest. Here, we present polychaete communities on the WS Shelf (AP, Filchner Trough: FT) including taxonomic and functional information linked to ice-cover regimes and food situation at the seafloor, and the attempt to predict their distribution based on bioregionalization. We used point data of fauna and sediment samples (grain size, TOC, TN, pigment content) from three expeditions with the RV Polarstern (PS81, PS118: AP; PS96: FT). Water-column data (temperature, salinity, chlorophyll a) was derived from water samples and CTD recordings and ice cover from 2010–2019. Additionally, 9 environmental parameters presented as raster grids from different sources were used for the bioregionalization (e.g. ice-cover variation, TOC, current speed, benthic terrain index). We observed heterogeneous polychaete communities, namely 6 taxonomic and 5 functional community types composed of a total of 34 families and 14 functional groups. Ice-cover variation and TOC were the most reliable parameters explaining the community patterns (> 39%), with a stronger relationship for functional than taxonomic communities, and have been included among other parameters within the bioregionalization approaches. Despite intensive efforts to adjust a joint clustering of biological and physical data or the Species Archetype Models (SAMs), no prediction could be run based on our input data. Consequently, the bioregionalization approach was applied by using physical data as surrogates. Although the four bioregions defined by k-means cluster algorithm did not reflect distribution patterns of either the taxonomic or functional communities, we can highlight potential vulnerable sampling sites for future research across the WS, e.g. the FT region with heterogenous community compositions across the WS. We assume that low fauna-sample densities compared to vast survey areas were limiting factors to run reliable models combining biological and physical information. Therefore, more biological and environmental data would allow to specify such models and to apply advanced models, e.g. the SAMs. Our findings underscore the relevance of filling spatial gaps of infauna sampling to improve modelling approaches and conservation strategies for vulnerable areas.

Emerging technologies enabling future Southern Ocean observations

Autosub Long Range vehicle 12 month deployment for the NERC Drivers of Oceanic Change in the Amundsen Sea (DeCAdeS) project

Mr Matthew Kingsland[1]

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The general pattern of Antarctic ice sheets is one of widespread retreat, but the rates and specific areas of retreat vary over multiyear to decadal timescales. Existing data is sparse and thus the uncertainty in projections is high. One cause of the sparse data is due to the difficulties with traditional mooring methods monitoring under sea ice with high yearly variability. Regularly moorings are deployed which cannot be recovered due to how the sea ice coverage changes from season to season. A location accessible one year may not be accessible the next time a vessel is nearby for recovery.

The UK's National Oceanography Centre is working on a solution to this challenge using its Autosub long range autonomous (ALR) vehicle. In 2022 the ALR completed the current longest autonomous deployment of a subsea vehicle completing ~2000km over 5 weeks depleting half of the vehicles battery. The vehicle was shore launched from Plymouth UK and drove out to the continental shelf completing science missions before driving back.

Under the NERC funded Drivers of Oceanic Change in the Amundsen Sea (DeCAdeS) project NOC and partners plan to deploy an ALR vehicle equipped with a specialized mooring system under an Antarctic ice sheet for 12 months after which the vehicle will drive it's self out to meet the waiting recovery vessel thus insuring recovery of the mooring data. The vehicle mooring system under development is a self contained system meaning the vehicle will carry all it's mooring equipment with it and thus does not need any on site infrastructure. Additionally the system is capable of 12 moorings making it possible for the vehicle to move locations up to 12 times over the deployment.

The plan for the DeCAdeS deployment is while under the ice the vehicle will be taking readings of environmental water conditions such as CTD data. Once a month the vehicle will wake up and travers a 200km out and back loop over 5 days before re-mooring again in roughly the same location. This is so that it is not only collecting temporal data but also spatial data through out a 12 month period.

This is a risky project presenting plenty of challenges including key aspects of autonomous vehicle deployments; navigation accuracy and reliability. In this presentation the vehicle and the project will be introduced along with initial designs and testing. Trials results and lessons learned from in water testing off Scotland in April 2023 will also be presented.

Toothfish fishing vessels as vessels of opportunity

Mr Rhys Arangio[1]

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The Coalition of Legal Toothfish Operators (COLTO) was founded in 2003 by industry members to eliminate illegal fishing for toothfish. Currently, COLTO has 49 members, 25 of whom are toothfish fishing companies, and encourages and helps its members develop and work towards best practice. Cumulatively, these companies have 35 vessels fishing in the Southern Ocean operating across 22 separate toothfish fisheries. These vessels can and do operate as vessels of opportunity for the collection of high quality scientific data and as research platforms. COLTO and its individual member organisations work closely with various research institutes, CCAMLR, RFMOs, Governments, and NGOs, and conduct research and data collection in collaboration with them. Many companies also conduct their own data collection and research programs.

Within the respective fisheries we operate in, there are standard fisheries management data collection programs that are widespread across the Southern Ocean, but also some which are specific to each fishery/company. These include:

- Collection of conductivity, temperature and depth (CTD) data
- Collection of benthic/longline camera footage
- Collection of acoustic/echosounder/sonar data
- Mark-recapture tag deployment
- Collection of biological data (e.g. samples for genetic and chemical analyses)
- Collection of biotic data (e.g. whale observations, deployment of hydrophones, sea lice traps, etc.).

All of these data are used for multiple purposes and projects; the outcomes of which are often shared with other companies/organisations to help establish and develop best practice.

Most COLTO fishing vessels have Electronic Monitoring (EM) Systems installed. Although this is primarily for regulatory purposes, EM has other potential utilities, such as for monitoring seabird and bycatch fish species populations, and improving understanding of interactions with each. As the technology is further developed, the ways in which EM (and coupled with artificial intelligence) can be used for environmental research and monitoring will also widen.

Our toothfish fishing vessels are operating across the Southern Ocean throughout much of the year and have an extensive cumulative areal coverage throughout the region, annually. This allows for repeatability of data collection both temporally and spatially. Toothfish fishing vessels have further benefits as research platforms: they carry two government approved scientific observers, who may be able to assist with various extra data collection duties; and some may have enough space to carry additional scientists and also specific scientific equipment. Due to the length of time that many vessels have been involved in science and research, the officers and crew are well practiced in various data collection methodologies. This in turn has strengthened a culture of collaboration and willingness to further the onboard science programs, within companies and crews. The investment and interest of vessels' crew is invaluable as their expertise and innovation can be used to better adapt science programs for successful operation from a fishing vessel.

COLTO and its members are already willing participants in many research programs. We hope this presentation sheds some light on ways we may be able to collaborate further with the science community.

Ocean properties and variability in front and beneath the Dotson Ice Shelf: direct observations from autonomous gliders and float profilers

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Interactions between oceans and ice sheets are crucial to the regulation of the global overturning circulation and the current acceleration of ice flow into the ocean and associated sea-level rise. However, challenges imposed by harsh, remote polar environments and by the complex, hazardous environment near and beneath ice shelves severely limit availability of the measurements required to advance understanding of key processes. As a step toward addressing this problem, three Seagliders, specifically adapted for acoustic navigation and autonomous operations under ice shelves, four EM-APEX profiling floats and acoustic navigation beacons were deployed at the Dotson ice shelf in West Antarctica in January 2018 for a year-long mission that includes extensive observations both in front of the ice shelf and deep within the ice shelf cavity. Sampling until February 2019, gliders collectively collected over 4000 hydrographic profiles and occupied over 30 sections in front of the ice shelf in all seasons, resolving ocean variability on horizontal scales of a few kilometers. Seagliders also occupied multiple axial and transverse sections within the cavity, the longest one covering 200 km in horizontal distance and lasting over 12 days. The acoustic navigation array allowed Seagliders to geolocate and navigate deep within the cavity interior. We present an overview of the glider and float mission's accomplishments.

Adaptive information gathering in the Southern Ocean using a team of autonomous vehicles

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The Southern Ocean is a vast and remote region that plays a critical role in regulating the Earth's climate and supporting marine biodiversity. Despite its importance, this environment is challenging to study due to its extreme conditions, including rough seas, strong winds, and icy waters. Traditional observing systems, such as research vessels and moored instruments, are limited in their ability to collect data from this region due to their high costs, logistical challenges, and restricted access. Advances in autonomous systems technology have created new possibilities for observing the Southern Ocean. Autonomous surface vehicles (ASVs) and autonomous underwater vehicles (AUVs) can operate in remote and hazardous environments without putting human operators at risk. These vehicles can be equipped with a range of advanced sensors, including acoustic instruments, cameras, and environmental sensors, to collect high-quality data on ocean currents, temperature, salinity, and other key variables.

One of the most significant advantages of autonomous vehicles is their ability to access regions that are inaccessible to traditional observing systems. AUVs can explore the ocean beneath the Antarctic ice sheets, providing researchers with valuable insights into the sub-ice environment and its impact on ocean circulation and ecosystem dynamics. By deploying ASVs and AUVs, researchers can gather data over broad temporal and spatial scales, providing a more comprehensive picture of the Southern Ocean's dynamics. In addition to expanding the scale and reach of data collection, autonomous systems can operate for extended periods without human intervention, reducing the need for costly ship-time and crew resources. These systems can also adapt to changing environmental conditions and adjust their mission plans in real-time, providing more flexibility for data collection. Furthermore, the use of autonomous systems can reduce the environmental footprint of ocean observation, as these vehicles produce fewer emissions and do not disturb the marine environment as much as traditional observing systems.

To maximize the effectiveness of autonomous systems for Southern Ocean observation, intelligent vehicle planning algorithms are needed to guide the vehicles' actions. CSIRO has developed a vehicle planner for adaptive information gathering with marine vehicle fleets, which can generate optimal plans for complex marine information gathering tasks in constrained underwater environments with limited communication bandwidth. This algorithm plans efficiently over long horizons and balances exploration of the environment with exploitation of features of interest within a limited mission duration, using prior knowledge to guide the decision-making process. The presentation highlights the capabilities of CSIRO's vehicle planner in generating comprehensive marine observations and addresses its potential to revolutionize the methods for observing the Southern Ocean. The use of autonomous surface and underwater vehicles, coupled with intelligent planning algorithms, offers tremendous potential to improve our understanding of this vital and challenging environment.

An array of in situ waves-in-ice instruments deployed during targeted observational experiment in winter 2022 in the Antarctic MIZ

Ms Robyn Verrinder[1,2,3], Michael Noyce[1,2,3], Jamie Jacobson[1,3], Lawrence Stanton[1,2,3], James Hepworth[2,4], Prof Amit Mishra[1], Prof Marcello Vichi[2,5]

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A variety of synoptic, seasonal and interannual drivers influence the forms and concentration of sea ice in the Marginal Ice Zone (MIZ) in the Southern Ocean. The temporal and spatial distribution of the ice and its physical and biological properties are directly related to the natural variability of the oceans and atmosphere, but also anthropogenic climate change. Climate and Earth System Models (ESMs) have limited sea ice variable parameterisations due to the scarcity of spatially distributed, high resolution, in situ measurements from the region, specifically during winter/spring. Improved design of cost-effective autonomous devices capable of persistent in situ sampling at finer spatial resolutions in the Antarctic MIZ, is key to obtaining datasets needed to improve ESMs and to validate remote-sensing products, particularly over the winter/spring period. This requires a multidisciplinary approach including engineering, oceanography and climate science.

This contribution presents the development and deployment of an observational array of low-cost ice-tethered instruments, designed in South Africa, to measure sub-daily environmental variability in the Antarctic MIZ. These affordable platforms are optimised to survive harsh Antarctic winter conditions and to improve in situ temporal and spatial data collection, with a focus on sea-ice motion induced by wind and waves. Each platform is able to store high-frequency inertial time-series data and to transmit key summary data including ice drift, wave parameters and environmental data via the Iridium satellite network.

An array of six instruments were deployed onto consolidated ice in the Antarctic MIZ, from the SA Agulhas II, during a Targeted Observational Experiment as part of Southern oCean seAsonaL Experiment (SCALE) Winter Cruise in July 2022. The experiment was designed to capture the impacts of a polar cyclone moving through the region, resulting in a significant change in the sea ice conditions in the MIZ. Four of the six instruments were collected after 2.5 to 4 days, before and after the cyclone passage period and high-frequency inertial time-series, ice drift and environmental data were retrieved from the platforms. To the authors' knowledge, these high-frequency inertial time-series datasets are the first of their kind for this region during winter and allow us to better characterise sea-ice motion during a large synoptic event. These measurements were complemented by advanced, ship-based, imaging of ice floes and waves using LiDAR, stereo visual and thermal cameras as well as measurements from other open water buoys (Finnish Meteorological Institute), deployed in the region during the same period. These unique high resolution data sets will be used to better characterise wave drivers of Antarctic sea-ice formation during winter and to inform Southern Hemisphere climate predictability.

Enabling Science with a Subsea Fiber Optic Cable for McMurdo Station, Antarctica

Dr. David Porter[2], Ms Ceci Rodriguez, Phd Bruce Howe, Mr. Patrick Smith

[1]Joint Task Force Smart Cable, United States, [2]National Science Foundation,

Human activity, whether scientific research, business operations or personal affairs, has become "digitized" as the world approaches the second quarter of the 21st Century. This digitalization of society is largely carried by 550 subsea telecommunications cables totaling 1.4M km in length, connecting all continents except Antarctica. The largest U.S. Antarctic research station, McMurdo, is wholly dependent upon satellite communications, residing at the very fringe of coverage by a small number of satellites. McMurdo Station has the largest population of all Antarctic research stations yet has the per-capita telecommunications bandwidth equivalent to the lowest quartile of global Internet bandwidth as measured by industry Internet speed tests - McMurdo would rank 104th out of 180 countries, with 1 ranking as the fastest.

In response, the National Science Foundation (NSF) intends to explore the implementation of a modern subsea telecommunications cable to interconnect McMurdo Station with the global Research and Education Network infrastructure via Australia or New Zealand. Such a cable promises capacities easily reaching 10 terabits per second, providing an essentially infinite capability to transform the conduct of scientific research and improve the care and well-being of personnel stationed there. Given the uniqueness of this cable and the region that it transects, NSF intends to explore the incorporation of science sensors and sensing capability into the cable design, creating a dual role to include essential observations of important variables such as ocean water column bottom pressure, ocean bottom water temperature, triaxial seismic ground motion and acoustic detection that will fill knowledge gaps of the underexplored Southern Ocean. The science observational potential of the cable can facilitate climate change monitoring by continuous observations of the Antarctic Circumpolar Current, a key component of the global ocean circulation system, as well as continuous distributed seismic monitoring of the Puysegur Trench subduction zone south of New Zealand – an area of significant tectonic plate movement and earthquake activity.

NSF completed an industry standard Desktop Study (DTS), incorporating “Antarctic unique” considerations which thus far indicates the cable landings, technical design, route, and installation to be feasible. Parallel small business innovative research efforts to develop essential science sensor modules show promise to address the sensor instrumentation goal of the cable according to the United Nations ITU/ WMO/UNESCO- IOC Joint Task Force on Science Monitoring and Reliable Telecommunications (SMART).

Beginning with a science workshop that addressed the basic question of the scientific merits of the concept, a summary of the cable’s merits and scientific potential, a survey of science sensor modalities, and study results are presented.

SMART Cables potential for the National Tsunami Warning Centers

Mr. Matias Sifon[1]

[1]Joint Task Force Smart Cable, United States

Tsunami early warning systems have significantly improved their capacities in the last decade, mainly focusing on threats from seismic sources, developing very efficient tools to face the challenge of major subduction earthquake events. On a multi-threat approach, new risks have appeared in our sight, especially last year with the eruption and subsequent tsunami from Hunga Tonga - Hunga Ha’apai, making more visible that non-seismic tsunamis are a real threat not only at a local level but also at a basin level. Unfortunately, at this point, given the uncertainty of the several different sources and mechanisms involved, it is not possible to forecast the impact with the in-place systems in real-time; hence non-seismic events are faced with a detect and monitor approach.

From this point of view, the huge challenge and difficulties of maintaining tsunameters and tide gauges operating along the Pacific ocean become a significant potential risk for early warnings, especially for island countries and territories that rely mainly on them. It is possible that their first warning will be the tsunami itself without prior notice. In this scenario, SMART cables bring a new approach to monitoring events at a basin level through pressure sensors, reducing uncertainty and giving organizations and communities a better time to face a threat once it has been triggered by improving the amount and distribution of tsunami detection points on the basin.

For example, Chile, with Eastern Island more than 2600 km from the closest Tide Gauge and approximately 3700 km from the continental coast, has only three possible monitoring points between the island and Hunga Tonga - Hunga Ha’apai. Another example is the Antarctic scientific bases, with only two tide gauges in the Antarctic peninsula with near-real-time transmission shared internationally.

At this moment, two possible future projects could be viable targets; the first is the Humboldt Cable connecting Valparaíso (Chile) and Sydney (Australia), potentially offering trans-pacific monitoring, and another to connect Puerto Williams (Chile) to Antarctica.

If these types of projects implement SMART sensors, this would widely improve the National Tsunami Warning Centers' capabilities in the Southern Pacific to warn remote communities early enough.

Observing the Ocean and Earth with SMART Subsea Cables

Ms Ceci Rodriguez, Phd Bruce Howe

[1]Joint Task Force Smart Cable, United States

The JTF SMART Subsea Cables (Joint Task Force, Science Monitoring and Reliable Telecommunications) is a United Nations effort uniting science with the telecom industry to provide the necessary strategic direction and leadership leading to the development of a sustained SMART subsea cable network. The network will monitor climate change including ocean heat content, circulation and sea level rise, provide early warning for earthquakes and tsunamis, and monitor seismic activity for earth structure and related hazards. All relate to disaster risk reduction and the informed sustainable development of coastal and offshore infrastructure, including the cables themselves and their mission of global connectivity.

From this year the JTF has an executive branch through the International Project Office that supports the JTF effort to make SMART cables the global standard. SMART cables are being more recognized by governments and the telecom industry. We have regional SMART cable systems such as the SMART Atlantic CAM ring system connecting the Portuguese mainland, Azores and Madeira (ready for service 2025). Planning is underway for a cable between Vanuatu and New Caledonia; between islands of Indonesia; from New Zealand to the Chatham Islands; and from Chile to Australia and to Antarctica. The US National Science Foundation has proposed a SMART cable from NZ to Antarctica. Such cables will bring sorely needed science connectivity with positive impacts in education, engagement, community and wellbeing; and the vital science enabled with the SMART submarine cable. The Southern Ocean Observing System would benefit from a number of these systems (and others to be proposed), providing highly reliable, 25 year life, real time, low (or no) maintenance, low-life time cost observations that leverage the 170 year old submarine cable industry.

Understanding the state and variability of Southern Ocean CO2 sea-air fluxes and carbon cycle

Assessing decadal anthropogenic carbon dioxide changes in the Ross Sea with stable carbon isotope measurements

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[1]Korea Polar Research Institute, South Korea

The ocean act as a major sink for atmospheric CO_2 and has absorbed approximately 30% of anthropogenic CO_2 emissions during the industrial era. In particular, up to 50% of this anthropogenic CO_2 has been absorbed into the Southern Ocean. Although the Ross Sea covers only 5% of the Southern Ocean, it plays a significant role in understanding global carbon budget changes due to its extremely cold temperature and strong biological pump in the coastal region. Therefore, it is crucial to evaluate the Southern Ocean's carbon uptake capacity to estimate future atmospheric CO_2 level changes as well as to monitor the effectiveness of global carbon emission reduction efforts.

In this study, to quantify the recent anthropogenic CO_2 input into the Ross Sea, we compared the $\delta^{13}C$ of DIC from the GLODAP data in 2011 with recent observational data collected during the R/V Araon's research cruise in 2020. We used the multiple linear regression method, using independent variables such as seawater temperature, salinity, oxygen, and total alkalinity, to reproduce the past and current $\delta^{13}C$ values. The results demonstrated that, in water columns deeper than 100 meters, the 13C of DIC in seawater has become more depleted in recent observations compared to the previous $\delta^{13}C$ measurements. indicating a continued strong inflow of anthropogenic CO_2 in the water columns below 100m. We estimated that during past 10 years (2011 - 2020), 11 ± 6mmol/kg of anthropogenic CO_2 was absorbed into the Ross Sea water column. Moreover, we also found that there was a noticeable difference in the amount of anthropogenic CO_2 between the eastern and western part of the Ross Sea.

Drivers of Marine CO2-Carbonate Chemistry in the Northern Antarctic Peninsula

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The Bransfield Strait is a climate change hotspot at the tip of the northern Antarctic Peninsula (NAP). The region is marked by a mixture of relatively warm waters from the Bellingshausen Sea with cold shelf waters from the Weddell Sea. Additionally, its deep central basin (>800 m) preserves seawater properties from the north-western Weddell Sea continental shelf. This study assessed long-term changes in carbonate chemistry in the Bransfield Strait and found that the hydrographic setting (i.e., a mixture between modified-Circumpolar Deep Water with Dense Shelf Water [DSW]) drives temporal variability of carbonate

parameters. The western basin has experienced decreases in pH (seawater scale) over the last three decades (1996–2019), varying from -0.003 to -0.017 pH units yr -1, while Ωar decreased from -0.01 to -0.07 yr -1 throughout the water column. The central basin was characterized by a high contribution of DSW with high carbon dioxide (CO2) content and the decomposition of organic matter produced and transported into its deep layer. With lower variability for all carbonate system variables, the eastern basin was likely regulated by internal mixing. Overall, the entire strait is almost reaching a CO2-saturated condition, highlighting how sensitive subpolar regions are to the effects of human-induced climate change.

Constraining the mechanisms of Southern Ocean dissolved iron distributions along GO-SHIP transect SR3 using optimum multiparameter analysis

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Across large parts of the Southern Ocean, the micronutrient iron is a limiting factor for marine primary productivity. This limitation reduces the efficiency of the biological pump that exports organic carbon to the deep ocean. Where the supply iron comes from, how it is transported and recycled, and where iron removal takes place, are critical mechanisms that need to be understood to assess the relationship between iron availability and primary productivity. While modelling efforts have furthered our understanding of iron biogeochemistry and its influence on carbon sequestration, observations of dissolved iron (dFe) and its relationship to physical, chemical and biological processes in the ocean are needed to both validate and inform model parameterisation. To this end, hydrographic and trace metal observations across the GO-SHIP section SR3, south of Tasmania, Australia have been analysed in tandem with the novel application of optimum multiparameter analysis. From the trace-metal distribution south of Australia, key differences in the drivers of dFe between oceanographic zones of the Southern Ocean were identified. In the subtropical zone, the source of dFe was constrained by waters advected off the continental shelf, and by remineralization in recirculated modified mode and intermediate water masses of the Tasman Outflow. In the subantarctic zone, the seasonal replenishment of dFe in Antarctic surface and mode waters appears to be sustained by iron recycling in the underlying mode and

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intermediate waters. In the southern zone, the dFe distribution is likely driven by dissolution and scavenging by high concentrations of particles along the Antarctic continental shelf and slope, entrained in high salinity shelf water. This approach to trace metal analysis may prove useful in future transects for separating out key mechanisms driving dissolved trace metal distributions. Further work will assess relationships between features in the dFe distribution, with that of the dissolved inorganic carbon distribution also afforded by optimum multiparameter analysis.

Interaction between multiple physical particle injection pumps and the impact on carbon export in the Southern Ocean

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The biological pump, which removes carbon from the surface ocean and regulates atmospheric carbon dioxide, comprises multiple processes that include but extend beyond gravitational settling of organic particles. Contributions to the biological pump that arise from the physical circulation and its variability are broadly referred to as physical particle injection pumps; a synthetic view of how these physical pumps interact with each other and other components of the biological pump does not yet exist.

In this study, observations from a quasi-Lagrangian float and ocean glider, deployed over a period of one month north of the Southern Ocean's Subantarctic Front and during the spring bloom as part of the SOLACE (Southern Ocean Large Areal Carbon Export) project. These measurements offer insight into high frequency, daily-to-monthly, fluctuations in the mixed layer pump and the eddy subduction pump. Estimated independently, each of these mechanisms contributes intermittent export fluxes on the order of several hundreds of mg of particulate organic carbon (POC) per day. The float and the glider produce similar estimates of the mixed layer pump, which has sustained weekly periods of entrainment and export fluxes with a magnitude of roughly 400 mg of POC per square meter per day. Export fluxes from the eddy subduction pump, based on a mixed layer instability scaling, occasionally exceed 500 mg of POC per square meter per day, with some periods associated with strong inferred vertical velocities and others with enhanced isopycnal slopes. Regimes also occur when a summation of the two pump estimates may misrepresent the total physical carbon flux. Disentangling contributions from different physical pump mechanisms will remain challenging with sparse data sets. Insight into how mesoscale stirring and submesocale velocities set the vertical structure of POC concentrations is identified as a key target to reduce uncertainty in global carbon export fluxes.

Exploring the euphotic zone residence time for lower cell water mass

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The global ocean overturning circulation consists of an upper and a lower cell. The lower cell only comes to the surface ocean far south in the Southern Ocean near Antarctica. Due to this limited area lower cell seawater is exposed to the surface, there is likely not enough time for marine phytoplankton to utilise the large amounts of nutrients that are present in lower cell seawater. Thus, the lower cell exports large amounts of nutrients which are not any longer available to fuel biological production and associated photosynthetic carbon fixation. If more of these nutrients would be utilised through photosynthetic carbon fixation, the associated atmospheric CO2 sequestration could be increased. Such an increase could for example be achieved through ocean iron fertilisation, which may be helpful to reduce atmospheric CO2 concentrations and counteract climate change.

Here we use a Lagrangian particle tracking in a high-resolution ocean-sea ice model to estimate how long water (and thus the nutrients in this water) resides in the surface ocean of the lower overturning circulation cell. We find that the cumulative residence time of virtual lagrangian particles in the upper 100 m is on average 2 years. When we further consider the light environment in this ocean region, which is heavily influenced by sea ice and seasonality, then water has only 0.4 year of cumulative residence time in light conditions that allow net phytoplankton growth. We conclude that this rather short residence time of nutrient-rich lower cell seawater in the light-exposed surface ocean constraints the potential for carbon fixation and thus climate geoengineering activities such as Southern Ocean Iron Fertilisation.

A meta-analysis of studies comparing profiling float pCO2 estimates with independent observations

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The Southern Ocean is believed to be a strong sink for atmospheric CO2 based on assessments of surface pCO2 from ships, moorings, and autonomous surface vehicles. However, these direct observations are very sparse, with only about 3% of all unique 1x1° monthly ocean grid cells sampled. The remaining 97% of the months and grid cells have no direct pCO2 observations. Global flux estimates require a variety of gap-filling methods that may interpolate or extrapolate data over thousands of kms and multiple years to create the values needed to compute global fluxes with annual resolution. BGC-Argo profiling floats equipped with pH sensors can provide an estimate of near surface pCO2 throughout the year. In the Southern Ocean, where there are particularly few ship-based observations in winter, arrays of these profiling floats can provide a unique source of observations that constrain air-sea CO2 fluxes. The floats deployed by the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project have been used to compute basin-scale fluxes of CO2 (Gray et al., 2018; Bushinsky et al., 2019) and they find that the Southern Ocean is a weaker sink for CO2 than previously believed. These surprising results have prompted a variety of independent assessments of the accuracy of pCO2 values estimated from profiling float pH. We are aware of 9 such studies that enable 10 assessments of potential bias in float-based pCO2. These studies all conclude that float-based pCO2 estimates are biased high by various amounts. Four of these studies are direct comparisons of float pCO2 to independently observed or calculated pCO2. The other six studies involve more indirect evaluations, such as comparisons of float based pCO2 with mapped pCO2 products created using machine learning methods. Here, we will present a meta-analysis for these studies, and update recent assessments of pCO2 comparisons when floats travel through the Drake Passage, where most ship-based observations of pCO2 during winter in the Southern Ocean are made. We conclude from this meta-analysis of prior work that profiling float pCO2 values have biases on the order of +3 µatm. This is substantially lower than asserted in some studies. These results suggest that prior estimates of CO2 flux in the Southern Ocean have over-estimated the sink, as suggested by Gray et al. (2018) and Bushinsky et al. (2019).

The Southern Ocean Carbon Gas Observatory (SCARGO) : an airborne platform for improving observational constraints on Southern Ocean CO2 fluxes

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The Southern Ocean Carbon Gas Observatory (SCARGO) will provide airborne CO2 observations across the Southern Ocean and to the South Pole with the aim to better understand the magnitude, seasonal evolution, and interannual variability of summer CO2. Years of observations and modeling studies indicate the Southern Ocean is a large and globally important sink for anthropogenic carbon dioxide. Nonetheless, there remains significant divergence among regional estimates of air-sea CO2 fluxes. A recent study that used a collection of models constrained by aircraft-based observations found weaker winter outgassing and stronger summer uptake relative to float-based estimates (Long et al., 2021). While aircraft and station-based observations have been valuable for estimating atmospheric inventories of CO2 and other gases, Southern Ocean CO2 flux estimates based on atmospheric inversion products have large uncertainties associated with modelled atmospheric transport and weak local signals relative to strong constraints from the Northern Hemisphere. A recently developed mass-weighted isentropic coordinate system can be implemented in a box-model approach for estimating surface fluxes from atmospheric observations (Jin et al., 2021). Defining diabatic mixing rates across isentropic surfaces based on the moist static energy budget overcomes atmospheric transport model biases. This approach highlights the power of airborne observing platforms for constraining Southern Ocean CO2 fluxes. Here we discuss our intended framework for using SCARGO data to constrain Southern Ocean CO2 fluxes. The relationship between sampling strategies and uncertainty was evaluated using a combination of atmospheric model and reanalysis data. Model-based tracer release experiments were used to indicate how air-sea fluxes influence the vertical profiles sampled along flight tracks. Preliminary SCARGO data collected during the 2022-2023 season are presented to illustrate this method and its promise as an operational constraint on this critical term in the global carbon budget.

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Long, M. C., Stephens, B. B., McKain, K., Sweeney, C., Keeling, R. F., Kort, E. A., et al. (2021). Strong Southern Ocean carbon uptake evident in airborne observations. Science, 374, 1275-1280.

Preliminary Results from the International Nutrient Inter-Comparison Voyage: Reducing Uncertainty in at-sea Nutrient Measurements

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At-sea macronutrient measurements are imperative for understanding marine biogeochemical cycling, however, the uncertainty associated with historical measurements is not always available, and inter-laboratory uncertainty is poorly quantified. Additionally, precision and accuracy can be affected by difficult conditions during at-sea analysis such as ship vibrations, fatigue, water purification, preparation of reagents from pre-weighed packages, and the use of reference materials. The International Nutrient Inter-Comparison Voyage (INIV; June 2023) enabled a unique comparison of 14 international laboratories, all of which use similar methods and instrumentation. During INIV analysts sampled and measured nutrient concentrations in seawater sampled from the same location at the same time aboard the RV Investigator following as close to their standard operating procedures as possible. This voyage quantified at-sea measurement uncertainty between laboratories, by the analysis of repeat measurements of certified reference materials, comparison of 'real-world' samples, analysis of calibration curves, and assessment of sampling and handling of samples through meta-data analysis. Here we will present preliminary results from this voyage and initial recommendations to enhance existing GO-SHIP best practices guidelines.

How Argo is transforming our understanding of the Southern Ocean in the global climate – Part 1

Polar Argo: current state, science highlights and technological advances

Esmee van Wijk[1,2], Dr Steve Rintoul[1,2], Polar Argo Mission Team members

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The deployment of ice-capable Argo floats has revolutionised observational oceanography in polar regions. Since the early 2000's, over 900 floats have been deployed in the Southern Ocean below 60°S collecting > 78,000 profiles and more than 500 floats have been deployed above 60°N, collecting around 40,000 profiles. Technological advancements such as software to help floats evade ice have led to survival rates close to those of regular Argo floats. New hardware to protect ice float sensors from damage by sea ice are being developed and tested. Systems that can track float trajectories under-ice are active in the Weddell Gyre and a variety of techniques are now available to estimate the position of under-ice profiles in post-processing. This talk will provide an overview of Polar Argo; from the early days of the program, to how the array is tracking against targets, to the most recent science highlights gleaned from Ice Argo data. Polar Argo floats have been used to show warming and a southward shift of fronts, estimate basal melt rate of glaciers, sample within ice shelf cavities, and have the potential to measure the draft of sea ice and icebergs. Research advances in the Arctic relevant to the Southern Ocean will also be highlighted including the potential for long-range acoustic tracking of floats and developments in sensors.

Observing dense shelf water in the ice-covered western Weddell Sea with intentionally-grounded Argo floats

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The Weddell Sea is characterized by the cyclonic Weddell Gyre circulation, which transports warm ocean waters from the ACC along the southern and western continental slopes. The continental shelves in the South and West are vast and for the most part inaccessible due to some of the thickest multi-year sea ice found anywhere around Antarctica. The sea ice formation and the ice shelf-ocean interaction underneath the Filchner Ronne Ice Shelf produce dense bottom waters, which are exported down and along the continental slope west of Filchner Trough. While, thanks to the use of Argo floats and oceanographic moorings, the Weddell Gyre circulation is comparatively well understood, the southwestern shelf and slope are largely uncharted territory. Throughout the last 2 decades, the Alfred-Wegener-Institute's Hybrid Antarctic Float Observing System (HAFOS) was instrumental in generating float-based observations throughout the Weddell Gyre. These under-ice deployments were generally supported by moored sound sources to assign approximate positions for the Argo-based CTD profiles.

In early 2021, we deployed five ice resilient APEX floats near the Filchner Trough on the southern Weddell Sea continental slope at water depths between 1000-1500 m. The floats included a new algorithm developed with the manufacturer, which implements a pre-assigned change in the parking depth after a certain period of time. The initial parking depth of 2000 m, as assigned during the first year, made the float nearly stationary as it rested on the shallower slope's seafloor in between profiles. After one year, the parking depth changed to 800 m, which then allowed the float to freely drift northwestward following the circulation around the Weddell Gyre. Interestingly, the float was constrained to the continental slope during the entire trajectory until it first surfaced in the ice-free northwestern Weddell Sea after nearly 2 years from deployment. During its passage, the float sampled the rarely observed cold bottom water that is exported off the southwestern shelf, and, for nearly 2 months, profiled underneath an iceberg. Overall, these recent APEX deployments provide considerable technical and scientific insights that may serve to guide future float deployments aiming at reducing the data gap in Weddell Sea regions that are difficult to access by ship. In this presentation, we discuss the latest results from a suite of ice resilient APEX floats, and discuss additional plans for Argo float measurements throughout the southern Weddell Sea.

Properties and pathways of Antarctic Bottom Water from five years of Deep Argo in the Australian-Antarctic Basin

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The formation and export of Antarctic Bottom Water (AABW) represent the southern downwelling limb of the global overturning circulation. Observations show decadal warming, freshening, and thinning of the AABW in all the deep southern basins, with the strongest signals in the Australian-Antarctic Basin. However, despite its significance in the global climate system, relatively few observations of AABW exist and many observations are along pre-determined hydrographic sections repeated years apart. Deep Argo is poised to change that. A pilot array of Deep Argo floats – delivering full-depth, year-round (including under-ice) in the Australian-Antarctic Basin since 2018 – has already begun to transform our understanding of temporal and spatial variability of AABW. Here, we present maps of the properties and pathways of AABW, and initial results on the seasonality of AABW in the Australian-Antarctic Basin measured by the Deep Argo array.

Antarctic sea ice formation and melt rates estimated from under-ice Argo observations

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Southern Ocean sea ice thickness is an important climate variable due to its impact on freshwater fluxes, ocean-atmosphere heat exchange, and momentum transfer. Yet monitoring the evolution of sea ice thickness from satellites has proven challenging, in part owing to a sparsity of in situ measurements for validation purposes. Here we estimate Antarctic sea ice formation and melt rates by constructing local mixed-layer salinity budgets along the drift trajectories of under-ice Argo profiling floats. Ice-related freshwater fluxes are inferred as the budget residual. We quantify budget contributions from entrainment, Ekman upwelling, and horizontal advection and diffusion using the Argo float measurements and auxiliary data sources, including atmospheric reanalysis, satellite retrievals of sea ice drift and concentration, and dynamic ocean topography. Freshwater fluxes from snow melt, the largest source of uncertainty in the salinity budget, are constrained using a Lagrangian reconstruction of snow mass accumulation on sea ice based on ERA5 reanalysis snowfall. We investigate the potential importance of snow loss processes such as sublimation and lead trapping of blowing snow. From the resulting salinity budget estimates, we derive a circumpolar climatology of Antarctic sea ice growth and melt for comparison with existing model- and satellite-based products.

The drivers of Winter Water's spatiotemporal variability over the annual cycle

Mr Theo Spira[1], Dr. Marcel du Plessis[1], Prof. Sebastiaan Swart[1]

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The Southern Ocean is central to the global overturning circulation, with south of the ACC being a region of significant upwelling of deep waters. Antarctic Winter Water (WW) is a water mass capping the upper overturning limb, acting as a conduit to transform deep waters into intermediate waters through entrainment early in its annual cycle. After subduction, WW subsequently acts to block underlying warm and carbon-rich waters from interacting with the surface layer, thereby arresting CO2 outgassing and surface warming. Using more than 15 years of quality controlled Argo, MEOP, ship-based and glider hydrographic profiles, we have produced a 1°x1° seasonal climatology of WW thickness, depth and core temperature. Using this high-resolution dataset, we describe the annual cycle of WW distribution and its properties from a circumpolar perspective for the first time. We find distinct regionality and seasonality in the WW cycle, which is influenced by the different dynamical systems that exist south of the ACC. WW extent is constrained to sea surface height in the Weddell Gyre. Upstream of large bathymetric features, such as Kerguelen Plateau and Pacific-Antarctic Ridge, display enhanced equatorward fluxes of WW. Downstream of these features and in regions where bathymetry does not drive barotropic steering on the distribution of WW exhibit the largest seasonal cycle of the most northern extent of WW, suggesting a key role of air-sea fluxes and subsurface mixing in WW temperature and thickness. This work shows that the regional heterogeneity of heat and freshwater fluxes, and processes that enhance lateral and vertical transport, have a guiding role on the lateral distribution of WW. We show localised regions of equatorward fluxes of cold WW, suggesting further evidence for an alternative view from the traditional "zonal mean" perspective of overturning circulation.

Poleward shift of Circumpolar Deep Water threatens the East Antarctic Ice Sheet

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Future sea-level rise projections carry large uncertainties, mainly driven by the unknown response of the Antarctic Ice Sheet to climate change. During the past four decades, the contribution of the East Antarctic Ice Sheet to sea-level rise has increased. However, unlike for West Antarctica, the causes of East Antarctic ice-mass loss are largely unexplored. Here, using oceanographic observations off East Antarctica (80–160° E) we show that mid-depth Circumpolar Deep Water has warmed by 0.8–2.0 °C along the continental slope between 1930–1990 and 2010–2018. Our results indicate that this warming may be implicated in East Antarctic ice-mass loss and coastal water-mass reorganization. Further, it is associated with an inter-decadal, summer-focused poleward shift of the westerlies over the Southern Ocean. Since this shift is predicted to persist into the twenty-first century, the oceanic heat supply to East Antarctica may continue to intensify, threatening the ice sheet's future stability.

An updated Gravest Empirical Mode climatology - utilising the wealth of Southern Ocean observations

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The Southern Ocean is extremely under sampled, with observational datasets extremely sparse through space and time. This has meant the oceanographic community is often relying on computationally expensive modelling simulations. In this work, we utilise the Argo array to create temperature and salinity Gravest Empirical Mode (GEM) fields in a region south-east of Australia. These fields are interpolated onto a dynamic height grid and are then combined with satellite derived absolute dynamic topography (ADT) to create daily temperature and salinity fields of the region from 1993 onwards. These fields are shown to accurately recreate in situ Argo temperature and salinity profiles, with the mean temperature residual less than 0.1°C and the mean salinity residual less than .005 PSU for the 0-2000 dbar water column. Gradient wind velocity fields are also derived from the time varying ADT fields to reproduce the Antarctic Circumpolar Current (ACC) velocity structure and innovatively include ageostrophic velocities that are capable of fluxing properties across stream. The cross-stream velocities derived from the gradient wind field enable further accuracy of the GEM fields within regions of strong curvature, an area where previous GEM fields have struggled to accurately recreate in situ measurements. This work celebrates the Argo array and shows how we can utilise it to recreate an accurate ocean product.

Insight into Southern Ocean eddies from Historical observations

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Surface properties of Southern Ocean eddies are changing, and the surface characteristics of eddies are interlinked with subsurface properties. Therefore, we expect changes in eddies' subsurface content and transport, including heat, salt and biogeochemical tracers. In this work, we aim to understand changes in eddies' available content anomalies, that is, the anomalous amount of properties carried by an eddy. However, we currently lack subsurface observations of Southern Ocean eddies at sufficient density to quantify these anomalies. To this end, we first build a database of eddy subsurface properties by extracting eddy observations from historical hydrographic data sets – GOSHIP and a dedicated eddy research voyage. Using this new eddy data set, we show unprecedented subsurface structure of anticyclonic eddies in the Southern Ocean. Furthermore, we show that eddy anomalies do not linearly vary from the centre to edge as we might expect them to. These results have implications for computing total physical and biogeochemical anomalous content of an eddy. Furthermore, this work provides a proof-of-concept for future exploration of Argo data and a baseline to evaluate climate models when they resolve eddies.

Emerging technologies enabling future Southern Ocean observations / Reshaping long-term observatories with focus on Antarctic and Southern Ocean: drivers, implementation and outcome

Simulating phytoplankton movement within the surface mixed layer to characterise the Southern Ocean spring bloom onset

Ms Tamara Schlosser[1], Pete Strutton[1], Kirralee Baker[1], Phillip Boyd[1]

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The Southern Ocean spring bloom of phytoplankton impacts the regional food web and marine carbon cycle, but we do not fully understand the timing and drivers of the spring bloom onset. The spring bloom onsets dependence on light availability, temperature, and grazing pressure is of ongoing discussion, with contrasting findings in the Southern Ocean literature. This divergence is partly due to how we define the surface mixed layer (SML). Long-term and depth-resolving observations of the biogeochemical variability were only made available relatively recently via the BGC-Argo program, where previously depth-averaging the entire SML, as in Sverdrup's critical depth hypothesis, was necessary. Here we employ a state-of-the-art turbulence closure model in combination with a Lagrangian particle tracking model to realistically simulate mixing in the SML and the random movement of phytoplankton in this layer. Using this combination of BGC-Argo observations and targeted simulations, we show how the average light history of thousands of individual plankton can deviate from an SML depth average, and the implications for resolving the environmental drivers of the Southern Ocean spring bloom onset.

Using Ship-Deployed High-Endurance Uncrewed Aerial Vehicles for the Study of Ocean/Ice Surface and Atmospheric Boundary Layer Processes

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Uncrewed aerial vehicles (UAVs) are proving to be an important modern sensing platform that supplement the sensing capabilities from platforms such as satellites, aircraft, research vessels, moorings, and gliders. Here, we present the development of cutting-edge payload instrumentation for UAVs that provides a new capability for ship-deployed operations to capture the high-resolution spatial and temporal variability of air-sea-ice interaction processes. The instrument payloads are built with a modular design for ease of interchangeability. Additionally, we implement a novel capability for fully-autonomous hybrid vertical take-off and landing (VTOL) fixed winged UAV from a moving ship on the open ocean. We demonstrated an endurance of over 12 hours carrying 15-lb payloads and the ability for multiple aircraft tandem orchestrated simultaneous flight. Real-time high-bandwidth data telemetry (100+ Megabits at up to 50 nm) allowed for the ability to adapt to observations in real-time for more efficient and targeted measurements towards our science goals. The modular payloads developed include thermal infrared, visible broadband and hyperspectral, and near-infrared hyperspectral high-resolution imaging. Additional capabilities include quantification of the longwave and shortwave hemispheric radiation budget (up- and down-welling) as well as direct air-sea turbulent fluxes. We highlight the use of UAVs for reconnaissance to find features of interest that included large-scale temperature fronts, mapping of glaciers, of landfast-ice and of

sea ice surface properties, and the discovery of a number of gigantic algal blooms. When deployed from research vessels, including the future Antarctic RV discussed at the recent NASEM Community Workshop on Antarctic Oceanography, UAVs will provide a transformational science prism unequaled using 1-D data snapshots from ships or moorings alone, and improve asset mobilization for targeted effi

The Southern Ocean Time Series – what can we learn from a decade of deep-water mooring observations?

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The Southern Ocean absorbs a significant fraction of anthropogenic heat and carbon dioxide (CO2) from the atmosphere and helps to shape the global climate. This oceanic service comes at a cost; the Southern Ocean is warming, freshening, becoming less oxygenated, and more acidic. The Subantarctic region experiences large natural variability in the physical, chemical and biological cycles, making anthropogenic changes, and their impacts on the marine ecosystem difficult to quantify. Establishing baselines for seasonal changes in hydrography, air sea exchange, biological productivity and export are important for tracking changes, as well as quantifying the magnitude and variability of carbon sequestration by the ocean. The Southern Ocean Time Series (SOTS) is the longest fixed biogeochemical time series in the Southern Ocean, providing direct observations at a level of detail not currently possible with remote sensing, and valuable for calibration and validation of other autonomous platforms. Using observations from two deep-water moorings deployed over more than a decade at the SOTS site, we evaluate biogeochemical variability across seasonal and interannual cycles, and share lessons from data quality control and data product generation.

Autonomous ocean-sea ice-atmosphere observatory for the Southern Ocean

Dr Petra Heil[1], Mr Anton Steketee[1], Dr Simon Alexander[1], Prof Alessandro Toffoli[2], Dr Craig Neill[3], Dr Helen Beggs[4], Dr John French[1], Prof Wolfgang Rack[5], Dr Jean Rabault[6]

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The Southern Ocean is provides critical climate and ecosystem functions at a global scale. It is also the meeting place for a raft of physico-bio-geochemical interactions and exchange. Fluxes across the ocean-sea ice-atmosphere interface in the Southern Ocean including its southern margins drive large-scale processes, some with global ramifications. For example, the Southern Ocean absorbs about quarter of anthropogenic carbon dioxide (CO2) from the atmosphere to modulate the climate system; freezing or melt of sea ice impacts the regional radiation balance. This richness of processes is contrasted by an obstructive absence of quality observations. Much of our knowledge about this region is from satellite remote sensing and few autonomous sensor packages. However, in situ (including near-field) observations are required to constrain remotely sensed data and to provide the required detail to inform at process level. To overcome this paucity of observations we designed an integrated ocean-sea ice-atmosphere underway observing system for vessel passing through sea ice. A version of this is currently being implemented on Australia's RSV Nuyina. The full system does include a suite of wave-ice cameras including stereo cameras and hyperspectral, an upward looking hyperspectral radiometer, X-Band ice/wave radar, ceilometer, micro-pulse lidar, rain radar and disdrometer, infrared SST autonomous radiometer, surface-water pC02 system, sea-ice thickness EM, snow radar, wave-ice pinger and a dedicated marine-cryosphere remote sensing facility. We note the crucial important to design, implement and operate the underway observatory as an integrated system to avoid any sampling or resolution conflicts. The system will evolve to reflect technological improvements and follow Best Practice procedures and promotes data stewardship. Conflicts with operational (navigational) and safety systems as well as nautical design challenges, such as limited options for locating instrumentation, e.g., on rails, with clear sky view or unrestricted nadir view. The underway system will operate regardless of the icebreaker being in research mode or in Voluntary Observing Ship mode. Data derived from RSV Nuyina's underway observations will be contributed to global efforts, such as the World Meteorological Organisation's Global Atmosphere Watch Baseline Surface Radiation Network, and Antarctic Regional Climate Centre, the International Oceanographic Data Exchange, the United Nations Educational, Scientific and Cultural Organization/ Intergovernmental Oceanographic Commission's International Ocean Carbon Coordination Project.

The South African Polar Research Infrastructure

Prof Juliet Hermes[1], Dr Tammy Morris, Prof Marcello Vichi, Mr Nish Devananthun, Prof Werner Nel, Dr Anne Treasure

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The South African Polar Research Infrastructure (SAPRI) was established in 2021. The vision of SAPRI is to enable balanced and transformed research growth across the multiplicity of marine and polar disciplines, and to maintain and further expand the world-class, long-term observational research infrastructure and datasets already established within South Africa polar and oceanographic research.This will benefit the governmental strategies for Antarctica and the sub-Antarctic islands and assist decision makers to formulate appropriate environmental policies that lessen the risk and vulnerability of global climate change on the regions which impact South Africa, but also which South Africa are custodian to.

The SAPRI mission is to transform the access to, and perception of, South African polar research for technicians, engineers, scientists of all disciplines, learners and students, government, private business and civil society and to further accelerate the implementation of the pan-African Science, Technology and Innovation agenda. In doing so SAPRI will create a co-designed, sustainable and responsive Research Infrastructure which produces Big Science stimulating innovative research and Intellectual Property generation that is of global relevance, and services the needs of all.

The SAPRI strategy is to ensure that the investment in research infrastructures translates into the generation of high impact science for the benefit of society, as well as the development of internationally recognised scientists, engineers and technicians and the retention of this capacity on the African continent. Through SAPRI, both the government and the research community have joined forces to: (1) contribute to the national obligation in terms of treaties, international agreements and scientific bodies, by means of sustained long-term observations and a single entry-point for expert consultations; (2) grow the scientific understanding of the large region of ocean and territories surrounding Southern Africa, through a substantial increase of state of the art infrastructure in support of research outputs and training capacity, in addition to the establishment of physical and digital infrastructures to simulate the polar environment in Africa and increase the diversity of contributions; (3) improve the relationship between polar science and society, by showing the relevance and scope of scientific and operational activities in this region through the Antarctic Legacy and the use of advanced digital technology; (4) unleash the innovation and commercial potential linked to developing instruments and services for operating in extreme and remote environments, such as the design of new sensors, polar vessels and the development of services from digital twin models.

To achieve its vision, SAPRI requires not only well trained scientists and technicians to operate and maintain the infrastructure investments, but also a mechanism to process, store and distribute the data being generated for impactful product development that will best serve the societal community and stakeholder interests in adaptation and mitigation strategies. Finally, this coordinated vision of SAPRI will require authentic leadership, dynamic management, innovative thinking, sustainable international collaborations, and out-of-the-box problem solving to deal with, not only the multiple stakeholders involved with SAPRI, but the extreme conditions in which these infrastructural resources will be deployed and used.

Macquarie Island Wildlife Monitoring Program: strategic monitoring for applied conservation and management

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Globally, seabird and marine mammal populations are under increasing pressure. Population declines persist for many species, with adverse interactions with commercial fisheries and climate change the principal threats. Understanding the connectivity between these predators and their changing environment is essential to understand the mechanisms driving population changes. At least 29 native vertebrate species breed on sub-Antarctic World Heritage listed Macquarie Island, with 62% of these species listed as threatened under either Australian and/or international criteria. We have established a new collaborative long-term monitoring program to determine the population size, status and trends of native vertebrates breeding Macquarie Island, and investigate links between environmental and anthropogenic drivers of population change, including climate change. We will develop and implement a strategic and adaptive monitoring program for these predators, including the review of current monitoring methodology to ensure survey design aligns with best practice techniques and provide data to help meet a range management and conservation priorities. The project also aims to trial and utilise new technology and innovations to improve the efficiency, accuracy and capability of surveys for priority taxa, and maximise the value of data collection efforts through collaboration with other key Antarctic research and observing programs. This program will provide a large dataset for ocean observing systems, such as the SOOS, as well as provide a mechanism for assessing how marine changes may be impacting predator populations. We will provide an overview of the current program and establish an avenue to connect with researchers and data curators. We want to ensure our work can link into the Southern Ocean Observing Systems and develop avenues for the inclusion of seabird and marine mammal population data into observing frameworks. These data would provide additional benefit to the current Essential Ocean Variables and improve the ability to monitor and assess the impact of marine ecosystem changes.

Bringing together approaches to reporting on within-species genetic diversity

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Genetic diversity underpins the ability of species to adapt and be resilient, which is particularly crucial at this time of climate change and biodiversity loss. Despite its fundamental importance, genetic diversity is under-reported within global and national indicators. When it is reported, the focus is often narrow and confined to domesticated or other commercially-valued species.

Several approaches have recently been proposed to address this shortfall in monitoring and reporting on the genetic diversity of wild species. These include the development of Essential Biodiversity Variables and Indicators for within-species genetic diversity. Whilst multiplicity of approaches is helpful in any development process, it can also lead to confusion amongst end users, and heighten a perception that conservation genetics is too abstract to be of practical use.

Given common themes within the various approaches to genetic diversity reporting, we – the developers of five of the different approaches – propose bringing them together. In this talk we will outline our proposal and discuss potential application to genetic monitoring in Antarctic and Southern Ocean ecosystems. We suggest a scorecard as a unifying reporting mechanism that enables consideration of all main threats to genetic diversity. This proposed combined approach captures the strengths of its components, within a framework that is practical for a wide range of end users, and that considers availability of resources, expertise, and data. Our proposal provides a mechanism for reporting on the pressures, state, conservation interventions and ecosystem services provided by genetic diversity.

DNA-based diet analysis of subantarctic predators to assess Southern Ocean food-web linkages and ecosystem change

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A key component of ecosystem monitoring programs that aim to support the maintenance of biodiversity and ecosystem function is sound knowledge of species composition and food web linkages. The design and implementation of these programs require consideration about what aspects of the ecosystem to measure, but also details such as their measurement methodologies and spatio-temporal coverage. These considerations have been elaborated in the framework of ecosystem Essential Ocean Variables (eEOVs). Diet information through predator-prey interactions are recommended as one of the proposed EOVs for observing changes in Southern Ocean ecosystems and this recommendation now needs to be developed into practicable sampling methods. DNA metabarcoding of predator scats allows the simultaneous investigation of the diet of different predator species, increasing our understanding of ecosystem connectivity and food web structure. By simultaneously studying the diet of six predator species on Macquarie Island across five years, we highlight the value of using scat DNA to assess biodiversity of prey species in the subantarctic. Through the collation of baseline and new dietary data, we provide a sound foundation for future monitoring programs measuring change in marine species diversity. We will discuss the considerations, challenges and feasibility of these methods for assessing ecosystem changes.

Observations to improve predictions of Southern Ocean ecosystems in the global context

KRILLPODYM: a mechanistic, spatially resolved model of Antarctic krill distribution and abundance

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Robust prediction of population responses to changing environments requires the integration of factors controlling population dynamics with processes affecting distribution. This is true everywhere but especially in polar pelagic environments. Biological cycles for many polar species are synchronised to extreme seasonality, while their distributions may be influenced by both the prevailing oceanic circulation and sea-ice distribution. Antarctic krill (krill, Euphausia superba) is one such species exhibiting a complex life history that is finely tuned to the extreme seasonality of the Southern Ocean. Dependencies on the timing of optimal seasonal conditions has led to concerns over the effects of future climate on krill's population status, particularly given the species' important role within Southern Ocean ecosystems.

Under a changing climate, established correlations between environment and species may breakdown. Developing capacity for predicting krill responses to climate change therefore requires methods that can explicitly consider the interplay between life history, biological conditions, and transport. The Spatial Ecosystem and Population Dynamics Model (SEAPODYM) is one such framework that integrates population and general circulation modelling to simulate the spatial dynamics of key organisms. We describe methodology for adapting SEAPODYM to create a novel model – KRILLPODYM – that generates spatially resolved, circumpolar estimates of krill biomass and demographics. The model combines krill life-history, ocean and ice circulation, and key habitat requirements to simulate krill spatial dynamics across its full life cycle.

Here, we present the first configuration and implementation of KRILLPODYM and discuss how this new model could be used to explore critical ecological questions addressing the influence of different environmental constraints on krill distribution, regional abundance and metapopulation dynamics, as well as, ultimately, how we might use the model to harvest scenarios and the effects of localised krill fishing on surrounding ecosystems.

Krill Growth Rates and Environmental Drivers in the Southern Ocean: Implications for Ecosystem Management and Sustainability

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Antarctic krill (hereafter: krill) is a key species in the Southern Ocean food web, serving as a primary food source for many marine predators. Krill plays a critical role in the carbon cycle by consuming and excreting phytoplankton, which helps to sequester carbon in the deep ocean. Due to their importance in the Southern Ocean ecosystem, it is crucial to understand the information required to best inform management decisions for the ecosystem and expanding fishery.

Growth rates of krill are commonly calculated using the Instantaneous Growth Rate (IGR) method. This is based on the difference between the uropod lengths of the moulted exoskeleton and the uropod lengths after moulting. The results from this process can be linked to the sex and stage of the krill and related to temporal and spatial variability.

The Australian Antarctic Division has led many voyages to the Southern Ocean, during which multiple IGR experiments have been run. Using data across 13 voyages undertaken during summer months from 1993 to 2019, we were able to compare growth rates between male, female and juvenile krill. These rates were then related to satellite derived sea surface temperature, chlorophyll and ice-free days.

Including robust growth rate data in krill models is important for understanding krill population dynamics, identifying environmental factors that impact the population, and predicting krill availability as a food source for marine predators. This information is crucial for informing conservation and management decisions aimed at ensuring the long-term sustainability of krill populations in the Southern Ocean.

Decadal timeseries of animal tracking, isotopes and biogeochemical modelling to simulate regional ecosystem variability in the Southern Ocean

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This project fills a fundamental gap in our understanding of how biodiversity responds to environmental changes (anthropogenic pressures, climate change and natural variability) using observations from a decadal tracking and archival tissue timeseries for a migratory species with circumpolar distribution, the Antarctic fur seal (Arctocephalus gazella). With novel combinations of electronic tagging, natural biogeochemical markers, and simulation modelling this project addresses how animal behaviour relates to physical habitats, prey availability and productivity in the Southern Ocean, and develop effective tools to monitor ecosystem change in remote oceanic environments. The key aims include: (1) calculate ocean-basin scale estimates of trophic position and food chain length in the Southern Ocean using archival tissues, (2) quantifying preferred foraging strategies and their stability, over decadal time scales, for a model, far-ranging, Southern Ocean marine predator, (3) quantifying heavy metal variability and ecosystem implications using novel bio-imaging techniques of archival tissues and (4) assessing the applicability of archival tissues as an integrated early warning signal for large-scale, Southern Ocean ecosystem change using biogeochemical simulation modelling. Stable isotopes are invaluable natural bio-tracers, coding information about movements, diet and physiology of animals. A major new frontier in marine isotope ecology lies in using isotope-enabled, global biogeochemical models to simulate isotopic compositions of key indicator species expected under differing, known movement behaviours. By coupling individual based movement models to temporally explicit isotope-enabled global models we assess the sensitivity of tissue isotope values to variations in environmental and physiological conditions (e.g. variations in temporal dynamics of the ecosystem, nutrient routing or animal foraging behaviours). Simulation modelling is used to generate a range of possible isotopic compositions associated with different scenarios. These simulated patterns are then compared to measured data providing a rich, and theoretically grounded experimental framework for the interpretation of stable isotope data. By coupling the integrated food web signal archived in the vibrissae of a key Southern Ocean predator with associated modelled tracks and dynamic biogeochemical models over decadal time scales, this project will improve our ability to quantify and predict the effects of changing climate and other environmental factors on Southern Ocean food web structure in space and time and link to essential ocean ecosystem variables. Development of simulation models to support assessments will be transferable to any mobile marine consumer and we will develop repositories for all model code together with instructional tutorials to detail how to modify models for alternative environments or taxa. Data products will be made available in a timely manner, providing information needed to underpin future management and adaptation strategies.

Lessons from the Marine Ecosystem Assessment for the Southern Ocean (MEASO) on measuring biological "sentinel" variables to support decision making

Dr Andrew Constable[1,2], Dr Monica Mathias Costa Muelbert[3], Dr Irene Schloss[4,5,6], Julian Gutt[7], Huw Griffiths[8], Susie Grant[8], Jessica Melbourne-Thomas[1,9]

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Participants in the Marine Ecosystem Assessment for the Southern Ocean (MEASO) have developed qualitative models of change in key components of Southern Ocean ecosystems. These models are being used to examine which biological variables will provide important signals of change in species and functional groups of direct interest to policy makers. These species include Antarctic krill, penguins, marine mammals, target species of fish, such as toothfish and icefish, and benthos often associated with vulnerable marine ecosystems. Variables representing these species are termed 'sentinel variables', which are a subset of ecosystem Essential Ocean Variables (eEOVs). Sentinels contribute directly to policy-makers through not only understanding the state of the system to be managed but also provide the data used for deciding on actions to be taken to meet conservation objectives in the Antarctic Treaty System. In this talk, we aim first to present this method of qualitatively assessing the value of prospective variables given the prognoses for drivers of change, such as fishing and climate change. Second, we consider the types of sentinel variables most promising for long-term assessments of change and for supporting end-to-end ecosystem modelling of change in the region. Lastly, we discuss a strategy for consolidating the set of variables useful for underpinning research and monitoring into the future, particularly in support of the Commission for the Conservation of Antarctic Marine Living Resources.

Satellite products and services for collection and delivery of essential observations of the Southern Ocean

Mr Oliver Palin[1]

[1]Cls Oceania, Hobart, Australia

The presentation will provide an overview of CLS Group's innovative satellite services for wildlife monitoring, ocean and meteorological data collection, with a focus on their application in the context of collection and delivery of essential observations of the Southern Ocean.

The main points that will be presented are:

- Evolution of ARGOS & Iridium satellite systems
- The Launch of the Kineis satellite constellation
- New CLS Group products: Goniometer and chipset modules
- Our know-how in innovative projects: telemetry, validation of satellite data, Oceanographic data collection in Southern Ocean (AAD KOMBI Lander)
- Our data offer: For over 30 years, CLS has provided state-of-the-art ocean data sets to scientific and institutional clients. CLS analysts provide daily bulletins and a range of online data visualization solutions, based on the type of data you want to view
- Vessel monitoring capabilities
- Our experience in various animal tracking and biologging projects

The Humpback Whale Sentinel Programme; Biomonitoring for Ecosystem and Chemical Surveillance

Professor Susan Bengtson Nash[1], Mr. John Totterdell, Dr. Claire Garrigue, Dr. Milton Marcondes, Dr. Cristina Castro, Dr Juliana Castrillon

[1]Griffith University, Australia

The polar regions of the Earth are warming faster than anywhere else on the planet, and melting of the Antarctic cryosphere is expected to carry massive local and global ramifications. Capturing the manifestation of climate change in the Antarctic and Southern Ocean region requires sustained and standardised monitoring through time, and across a large spatial scale. The challenging conditions of work in the region render such observations expensive and difficult to obtain, and thus susceptible to missed observations. These factors have led to widespread efforts to develop remote observation systems and technologies for the Antarctic region. Capturing ecosystems' response to climate change is one of the most challenging, but most pressing needs for predicting the impact of accelerated climate change. The Antarctic ecosystem is unique in that almost all Antarctic predators rely directly or indirectly on Antarctic krill. The sympagic life history of krill leaves the species, and therefore dependent consumers, particularly vulnerable in a warming climate with ecosystem cascades predicted. The keystone role of krill in the Antarctic sea-ice ecosystem underscores the need to understand temporal and spatial population dynamics of krill around the Antarctic region. This need has long been recognized by the Convention for Antarctic Marine Living Resources (CCAMLR), which takes an ecosystem approach to monitoring of krill. To date the CCAMLR Ecosystem Monitoring Program uses penguins, seals, and flying seabirds as sentinels of the Antarctic sea-ice ecosystem. More recently, the southern hemisphere humpback whales sentinel parameters of adipose stores, diet, and fecundity, have been shown to oscillate closely with environmental conditions in their Antarctic feeding grounds. Identification of these sentinel parameters, and the development of novel chemical and biochemical tracers for their quantification, paved the way for implementation of the Humpback Whale Sentinel Programme (HWSP), a circum-polar biomonitoring program for long-term surveillance of climate change and chemical pollution in the Antarctic sea-ice ecosystem. Here we present 9 years of temporal monitoring data from the east-coast of Australia migrating humpback whale population (2008-2017). The results of six ecophysiological markers of population adiposity, diet, and fecundity clearly indicate a negative trend in 2011 and 2017, coincident with the extreme 2010/11 La Niña event, as well as a 2017 sea-ice low. These findings lend further support for the use of migratory Antarctic krill feeders as powerful and practical sentinels of the Antarctic sea-ice ecosystem.

The HWSP is the primary surveillance activity of the Antarctic Monitoring and Assessment Programme (AnMAP), an endorsed United Nations Ocean Decade Activity. Since 2017, the HWSP has expanded to incorporate an additional 5 humpback whale breeding stocks around the southern hemisphere, facilitating monitoring of the circum-Antarctic region. Sustained, coordinated, and spatially comprehensive efforts, such as those under the HWSP will offer the ability to investigate the ecosystem impacts of climate anomalies, such as the 2020 heatwaves in Antarctica, as well as capture directional ecosystem and pollution trends.

Using satellites to monitor catastrophic breeding failures at emperor penguin colonies linked to historic low sea ice extents.

Dr Peter Fretwell[1]

[1]British Antarctic Survey, Cambridge, United Kingdom

Free to use, optical satellites with medium or high spatial resolution and high temporal resolution are transforming the way we can monitor remote, colonial-breeding marine predators. This has been highlighted by ongoing studies on the catastrophic breeding failures of emperor penguins linked to sudden early sea ice loss in 2021 and 2022. These years have seen record-breaking low sea ice extents around the Southern Ocean, following on from two other extreme low sea ice years in 2016 and 2017. The effect that this has had on remote breeding sites, which are difficult to reach on the ground, can be monitored regularly by satellites. We present results from 5 years of monitoring between 2018 and 2022 of all 66 colony sites of emperor penguins around Antarctica.

Modelling the krill-centred ecosystem: how far can we push it?

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The Southern Ocean is described as a krill-centered ecosystem. This reflects the role of Antarctic krill in providing the key link in the dominant energy pathway from primary production through to many of the region's top predators. Krill are also the subject of the Southern Ocean's largest fishery.

Krill have evolved to succeed in the extreme seasonality of the Southern Ocean. However, given the narrow geographical range in which they thrive it is clear they achieve this through coupling their life history with certain key environmental drivers. Understanding these environmental drivers and how they control krill population success is critical for informing both conservation and management of the species in current and various projected future climates.

We present results from our work to better understand the relationship between krill and their environment. Our approach is two-fold: improve our understanding of how krill respond to environmental drivers (krill life-cycle modelling) and improve our modelling and assessment of the Southern Ocean environment (ocean-sea ice modelling).

Recent results have demonstrated our ability to successfully reproduce regions of good spawning habitat and growth potential for adult krill. We are now using Lagrangian transport to understand how different regions may be linked during the krill life cycle. We have also investigated ACCESS-OM2, a high-resolution ocean-sea ice model , as a tool to reproduce critical habitat characteristics. Our next focus is to combine an ocean-sea ice model with the complete krill life cycle to provide circumpolar estimates of the krill population and its demographics. We report on our preliminary developments in this endeavour.

How Argo is transforming our understanding of the Southern Ocean in the global climate – Part 2

SOCCOM (Southern Ocean Carbon and Climate Observations and Modeling): Biogeochemical Argo, State Estimation and Earth System Modeling

Professor Lynne Talley[1], Professor Jorge Sarmiento[2], Dr. Kenneth Johnson[3], Dr. Lionel Arteaga[4,5], Professor Seth Bushinsky[6], Dr. Heidi Cullen[3], Professor Sarah Gille[1], Professor Alison Gray[7], Dr. Roberta Hotinski[2], Ms. Tanya Maurer[3], Dr. Matthew Mazloff[1], Professor Stephen Riser[7], Professor Joellen Russell[8], Professor Oscar Schofield[9], Dr. Ariane Verdy[1]

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The Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project seeks to understand Southern Ocean processes for carbon and biogeochemistry central to climate change, and to apply this understanding to improvement of Southern Ocean processes in Earth System Models. The Southern Ocean serves as the primary gateway through which the intermediate, deep, and bottom waters of the ocean interact with the surface ocean (and thus the atmosphere and cryosphere), and it has a profound influence on the oceanic uptake of anthropogenic carbon and heat as well as nutrient resupply from the abyss to the surface. Yet it has been the least observed and understood region of the world ocean. SOCCOM was implemented in 2014 with a goal to remedy this deficit in observations and understanding. SOCCOM is based on two major advances that are transforming understanding of the Southern Ocean: (1) development of new biogeochemical (BGC) sensors mounted on autonomous profiling floats that allow sampling of ocean biogeochemistry in 3-dimensional space with a temporal resolution of five to ten days, and (2) growth in computational resources and physical understanding to develop fully coupled climate models that can represent crucial mesoscale processes in the Southern Ocean, as well as corresponding models that assimilate observations to produce a state estimate.

(1) SOCCOM's observational component - deployment of profiling floats with oxygen, nitrate, pH and bio-optical sensors south of 30S, including in the large sea ice region - is generating vast amounts of new biogeochemical data that provide a year-round view of the Southern Ocean from the surface to 2000 m. After 9 years of operation, SOCCOM has deployed more than 270 profiling floats, collecting over 24,000 vertical profiles throughout the Southern Ocean. SOCCOM pioneered and remains central to development of the algorithms that connect the float-measured parameters to the full carbon budget. The float data and derived parameters are being widely used for analyses of spatial and temporal processes that were heretofore undescribed, including full annual cycles of biogeochemistry and biology from the ice-covered high latitudes to the Southern Hemisphere subtropics. The observations are now numerous enough to contribute to climatologies. We have characterized, among other things, critical winter carbon flux patterns, seasonal and spatial distributions of biomass and productivity, under-ice circulation, and emerging climate trends including buoyancy-driven ACC acceleration and acidification of the near-surface Southern Ocean.

(2) Coupled climate and ocean-only models have been employed in SOCCOM to study the Southern Ocean's evolution under changing winds, freshwater, sea ice and glacial melt; the processes that govern its mechanisms of heat and carbon uptake; and associated changes in circulation, sea ice, and acidification. The SOCCOM BGC float data have been incorporated

as constraints in the 4DVar BGC Southern Ocean State Estimate (B-SOSE) developed by SOCCOM. B-SOSE outputs are widely used to assist with analysis of the direct measurements, and to provide closed budgets to study underlying ocean physics and biogeochemistry.

SOCCOM's capability to meet the observing system priorities outlined for a notional UN Ocean Decade Southern Ocean observing system is assessed.

Southern Ocean Biological Response to Dust Quantified by BGC-Argo Observations

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Primary productivity in the pelagic Southern Ocean is seasonally limited by iron and light. Natural iron fertilization of the Southern Ocean by windblown iron-bearing dust has been hypothesized to enhance biological productivity, increase carbon export and modulate the global climate. However, this process has never been quantified across the Southern Ocean and at annual time scales. Here, we present the first empirical evidence of the Southern Ocean-wide biological response to dust-iron fertilization. Based on BGC-Argo nitrate observations, collected between 2012 and 2022, and simulated dust deposition (2015–2019, ACCESS-AM2 model output) we derived statistically significant relationships between dust fluxes and annual net community production (ANCP) in the iron-limited Southern Ocean. By applying these relationships to appropriate dust deposition model outputs, we computed present-day and last glacial maximum (LGM) ANCP maps and the fraction of ANCP supported by dust-iron fertilization. We estimate that during the LGM, when dust fluxes were on average 6.5x higher than today, dust-iron supported 54–74% (0.92–1.32 Pg C yr^{-1}) of the productivity in the perennially ice-free Southern Ocean south of 30°S, compared to 19–53% (0.19–0.54 Pg C yr^{-1}) at present. Our results suggest that the area of the Southern Ocean experiencing nitrate depletion during the productive period due to excessive dust-iron supply was twice as large under increased glacial dust loads (2.8 million km^2, or 36% of the Southern Ocean), compared to today (1.4 million km^2, 18%). These results underscore the profound impact dust had during the LGM, and still has today, on the global carbon cycle and climate. Our findings highlight the importance of developing a comprehensive understanding of the

biological response across the Southern Ocean to inter-annual fluctuations in dust supply, as this is critical for accurate future climate projections.

Sea Surface Kinetic Energy as a Proxy for Phytoplankton Light Limitation in the Summer Pelagic Southern Ocean

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The pelagic Southern Ocean is a high-nutrient, low-chlorophyll ecosystem. Here, phytoplankton growth is colimited by iron supply and light availability. This creates a general expectation that when light is available in the austral summer (shallow mixing depths), phytoplankton concentrations may be high or low depending on the delivery of iron to the surface layer. When light is not adequate (deep mixing depths), phytoplankton concentrations will likely be low, even if iron is available. Here we show that low surface kinetic energy behaves like a necessary but not sufficient condition for high chlorophyll concentrations. In high kinetic energy conditions, high chlorophyll concentrations are rare. Conversely, under low kinetic energy conditions, both high and low chlorophyll concentrations were observed. We show that higher kinetic energy conditions are related to deeper mixed layers, which is likely a proxy for local light conditions. Probabilistic models of chlorophyll based on surface kinetic energy were able to describe 30% of the spatial variability in monthly chlorophyll climatologies. This means that local light availability, proxied by mixing through kinetic energy, significantly shapes the spatial distribution of chlorophyll in the Southern Ocean. We suggest that regions with consistently higher kinetic energy may not be as sensitive to iron inputs compared to historic iron addition experiments, which were conducted in low surface kinetic energy conditions.

What lies beneath? Deep diatom communities are observed across the Southern Ocean

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Subsurface Chlorophyll Maxima (SCMs) are observed during summertime across the Southern Ocean. Regional ship-based studies have led to a number of theories that explain the formation of these SCMs. Yet, the Southern Ocean SCM remains enigmatic at a basin-scale. Biogeochemical Argo (BGC-Argo) floats extend the spatial and temporal coverage of SCMs beyond the power of ships and satellites, offering insights to large scale mechanisms that form SCMs.

This presentation will cover findings from a doctoral thesis which links observations of deep diatom communities from ship-based studies to subsurface fluorescence maxima observed from Biogeochemical Argo floats. The thesis considers observations of subsurface fluorescence maxima (SFMs) from floats, questioning if observations of SFMs are in actuality SCMs. Coincident observations of chlorophyll fluorescence and chlorophyll concentrations show that corrections of non-photochemical quenching (NPQ) and changes in fluorescence yield due to community shifts can lead to a SFM but no SCM. After considering and quantifying these effects, we determine that SCMs are found in around 40 % of summertime BGC-Argo observations. Furthermore, we link optical properties of deep diatom communities to these observations providing evidence that sinking diatoms form most SCMs in the Southern Ocean. Finally, potential theories surrounding the formation of these diatom SCMs are tested through correlation with environmental variables at a large-scale.

Its shown that these SCMs are currently not accurately observed, can skew surface measurements and are not captured in models. Thus, this work offers insight into Southern Ocean SCMs to pave the way for future improvements by bioeochemical modellers and ocean observers.

The Effects of Mesoscale Eddies on Southern Ocean Biogeochemistry

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The Southern Ocean modulates global biogeochemical (BGC) cycles substantially, affecting biological production and the global air-sea balance of carbon dioxide and oxygen. Concurrently, the Southern Ocean is rich in highly dynamic mesoscale eddies. These eddies have the potential to alter local carbon, nutrient, and oxygen distributions through eddy pumping, stirring, and trapping. Additionally, the strong westerly winds could result in significant eddy-induced Ekman pumping that has the opposite direction and offsets the effect from eddy pumping. However, the role of mesoscale eddies on upper-ocean Southern Ocean biogeochemistry has not been quantified observationally at a regional scale.

Although this region is historically under-sampled, we now have nearly a decade of BGC observations from Argo floats deployed as part of the Southern Ocean Carbon and Climate Observations and Modeling project (SOCCOM). Moreover, the Aviso database provides us with a robust assessment of eddies as detected by satellite altimeter measurements. Together, the two datasets allow us to investigate the three-dimensional structure of the biogeochemistry in Southern Ocean eddies. Here, we co-locate the Southern Ocean eddies with BGC Argo floats to present the composite vertical and horizontal structures of dissolved inorganic carbon (DIC), oxygen, and nitrate inside anticyclonic and cyclonic eddies compared to the mean climatological fields. We conduct this analysis in several subregions with different dominant processes. We find more DIC and nitrate in cyclonic eddies, which we attribute to upward pumping. We also find more oxygen near the surface as the upwelled nutrients enhance biological production there and less oxygen at depth, consistent with enhanced remineralization in cyclonic eddies. The opposite is true for anticyclonic eddies due to downward pumping (less DIC and nitrate; less oxygen near the surface, more oxygen at depth). Our findings enable us to interpret the influence of mesoscale eddies on the overall Southern Ocean carbon fluxes and biogeochemistry, including assessing the relative dominance of eddy pumping and eddy-induced Ekman pumping in different subregions of the Southern Ocean.

Southern Ocean Acidification Revealed by Biogeochemical-Argo Floats

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Ocean acidification has potentially large impacts on calcifying organisms and ecosystems. Argo floats equipped with biogeochemical (BGC) sensors have been continuously measuring Southern Ocean pH since 2014. These BGC-Argo floats were deployed as part of the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project. Here we present a SOCCOM-era Objectively Mapped pH (SOM-pH) 2014-2019 climatology and explain the method for constructing this product. We show example SOM-pH fields demonstrating the spatial and temporal structure of Southern Ocean pH. Comparison with previous ship-based measurements reveals decreases in pH of up to 0.02 per decade, with a structure decaying with depth. An assessment of the trend structure on meridional regions reveals a pattern indicative of the meridional overturning circulation. Upwelling waters that haven't been in recent contact with the atmosphere show negligible or small trends, while surface and downwelling waters that have had more exposure to the atmosphere show the strongest trends. Thus comparison of this new BGC-Argo mapped pH estimate to historic observations allows quantifying the structure of Southern Ocean acidification.

Subantarctic pCO2 estimated from a biogeochemical float: comparison with moored observations reinforces the importance of spatial and temporal variability

Dr Cathryn Wynn-Edwards[1,2], Dr Elizabeth Shadwick[1,2], Mr Peter Jansen[1], Dr Christina Schallenberg[1,2], Dr Tanya Maurer[3], Dr Sutton Adrienne[4]

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Understanding the size and future direction of natural ocean carbon sinks is critical for the projection of atmospheric CO2 levels. The magnitude of the Southern Ocean carbon flux has varied significantly over past decades and mechanisms behind this variability are still under debate. While high accuracy observations, e.g. from ships and moored platforms, are important to improve models and track efforts to reduce anthropogenic carbon emissions, they are limited through space and time. Observations from autonomous platforms with emerging biogeochemical capabilities, e.g. profiling floats, provide greater spatial and temporal coverage. However, the absolute accuracy of seawater CO2 partial pressure (pCO2) derived from pH sensors on these floats is not well constrained. Here we capitalize on data collected for over a year by a biogeochemical (BGC) Argo float near the Southern Ocean Time Series observatory to evaluate the accuracy of pCO2 estimates from floats beyond the initial in water comparisons at deployment. By utilizing high quality pCO2 observations from moorings and shipboard underway measurements as well as estimates from CTD casts, we found that float-based pCO2 estimates were predominantly higher than mooring pCO2 observations, with a potential high bias of 3 – 11 μatm and a latitudinal gradient of increasing pCO2 southward, similar to previous reports and close to the current state of the sensor capability. Continued

validation efforts, using measurements with known and sufficient accuracy, are vital in the continued assessment of float based pCO2 estimates, especially in a highly dynamic region such as the subantarctic Zone of the Southern Ocean.

Under-ice Float Observations from the SOCCOM Array: Examples and Climatologies

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The SOCCOM program has deployed over 260 floats in the Antarctic since 2014, with many of these profiling in the wintertime sea ice zone. Nearly 4000 profiles of temperature, salinity, and BGC variables have been collected under the ice. These profiles exhibit phenomena such as wintertime convection, supercooling, phytoplankton blooms, and intrusive mixing of shelf waters. In addition to discussing case studies of these phenomena, we present under-ice climatologies of the BGC variables derived from both directly measured and inferred quantities such as pCO2 and DIC from this ensemble of profiles.

Southern Ocean plankton: productivity, diversity, food-web dynamics, time-series & biogeochemistry

Under-ice phytoplankton in autumn uncovered by southern elephant seals in the East Antarctic

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While seasonal sea ice formation begins in autumn, the potential for under-ice phytoplankton remains hidden from satellites and have only recently started to be investigated by BGC-Argo floats and in-situ observations. Therefore, a gap remains in understanding how much biomass accumulates in autumn phytoplankton blooms within the sea ice zone and what conditions promote their existence. This study aims to examine the spatial-temporal dynamics and physical drivers of under-ice and ice-edge phytoplankton blooms in austral autumn off East Antarctica between 2018-2021. Nine southern elephant seals (Mirounga leonina) equipped with bio-logging devices measuring fluorescence, light and CTD data are utilized in combination with sea ice concentration and BGC-Argo floats to conduct a spatial analysis. Preliminary results show that the southern elephant seals within >15% ice cover document enhanced chlorophyll a fluorescence (> 5 mg m-3). The next step is to attempt to determine what physical conditions promote the biomass and whether these phytoplankton are advected below the ice or commenced in situ.

Trends in Southern Ocean phytoplankton iron stress, primary production and bloom phenology

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Climate change is eliciting widespread adjustments to the physical and chemical environment of the oceans, which affects the distribution and seasonal cycle of phytoplankton primary production (NPP). This in turn impacts ecosystem function and the transfer of carbon, energy and nutrients through food webs with complex feedbacks on ocean biogeochemistry and climate. By applying a number of NPP algorithms to 25 years of remote sensing data we show that almost two thirds of the Southern Ocean is typified by significant negative trends in production. Moreover, we provide evidence of a significant multi-decadal increase in phytoplankton iron stress (from in situ BGC-Argo and ship-based platforms) that could potentially be a cause. Concomitant with these declines in NPP are significant shifts in the amplitude, timing, duration and characteristics of variability of phytoplankton seasonal blooms. Investigating relationships between observed trends and prominent climate drivers highlights regional sensitivities and the complexities of multiple interacting aspects of a changing climate. The majority of these trends differ to those currently being predicted by earth system models, suggesting that they may be underestimating ongoing change in the Southern Ocean, a region where the biological carbon pump is considered to be particularly important. Adjustments of this magnitude at the base of the food web can de-synchronise energy transfer to higher trophic levels, threatening ecosystem services and impacting global climate by altering natural CO_2 uptake.

Variations in the particle size distribution and chlorophyll-to-carbon ratio in the Southern Ocean

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Marine particle size distribution (PSD) is an important characteristic of suspended particles and a fundamental property that influences carbon export. However, PSD variation and associated chlorophyll-to-carbon ratio in the Southern Ocean (SO) are not entirely clear. Here, we used bio-optical dataset collected during the ACE (Antarctic Circumpolar Expedition) and SOLACE (Southern Ocean Large Area Carbon Export) cruises to understand the particle-based bio-optical properties and the relationships related to carbon export. We found that the particular backscattering coefficient in the SO was generally higher than the temperate oceans. Chlorophyll-to-carbon ratios showed large variability, especially in the ocean fronts.

Bottom-up controls on summer phytoplankton dynamics in the surface waters of the Gerlache-Bismarck Strait area, Western Antarctic Peninsula

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We evaluated the bottom-up mechanisms that control phytoplankton growth in the highly productive Gerlache-Bismarck Strait region spanning inshore, fjord and coastal environments. A coastal region surrounded by islands, narrow straits and glaciers, the area is expected to capture a gradient between trace metal rich inshore waters and trace metal deficient offshore waters where micronutrients such as iron or manganese may proximally limit phytoplankton growth. Whereas macronutrient distributions are primarily controlled by watermass mixing and biological drawdown, multiple additional processes including scavenging, benthic and freshwater associated sources affect the inventory of trace metals. Here, we report the summer spatial distribution of surface seawater dissolved trace metals (dissolved Fe and Mn), macronutrients and key oceanographic and biological parameters along the Gerlache-Bismarck Strait to understand processes that control surface phytoplankton dynamics. We used GAMs to evaluate the main drivers that modulate the concentrations of micronutrients and phytoplankton biomass. Chlorophyll and nitrate were significant predictors explaining the spatial distribution of dFe and dMn, representing the biological uptake of trace metals. Finally, diatoms dominated the phytoplankton community in areas of higher biomass that were associated with higher glacial dischage or higher silicate concentrations due to CDW influence. A redundancy analysis (RDA) revealed diatoms displaying species-specific relationships with silicate and dissolved iron, while dinoflagellate and flagellates were more abundant in iron rich waters.

Low-Fe availability reduces the photosynthetic competency of ice algae upon discharge from sea ice

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Sea-ice algae significantly contribute to the annual primary production of polar seas and also seed extensive ice-edge blooms. Ice algae must rapidly acclimate to dynamic light environments, from the low light under or within sea ice to high light in open waters. Iron (Fe) deficiency has been reported for diatoms in eastern Antarctic pack ice. Low Fe availability reduces photosynthetic plasticity, leading to reduced ice-algal primary production. The effects of multiple co-stressors associated with large environmental fluctuations in the sea-ice zone (i.e., freeze up: low temperatures and high brine salinity; ice melt: sudden intense light exposure under chronic Fe starvation) on the photophysiology of the sequenced ice diatom Fragilariopsis cylindrus were investigated in a series of ice tank experiments under different Fe and light availabilities. Over 20 days in the ice tank, the diatom was incubated in artificial ice at Fe-replete and low-Fe sea ice ([total Fe] = 400 nM and 20 nM, respectively) in high light (HL) and low light (LL) conditions. Ice samples collected from the ice tank were selected randomly and melted ice exposed to intense light to simulate light conditions typical for melting ice in situ. Cell photophysiology was estimated with a fast repetition rate fluorometer (FRRf). Before ice formation and at low-Fe availability, the diatom showed a lower maximum photochemical quantum yield (Fv/Fm) of photosystem II (PSII). When algal cells were frozen into the ice, the Fv/Fm values decreased regardless of Fe and light availabilities, possibly due to the damage of PSII reaction centres or stress of high brine salinity on the downstream components of PSII. Expression of the

rbcL gene, encoding RuBisCO, was highly upregulated, suggesting an acclimation to the ice environment. Cells within the ice showed almost identical levels of Fv/Fm regardless of Fe and light availabilities, demonstrating that they could maintain photosynthetic capability throughout the in-ice periods and increased photoprotection through non-photochemical quenching (NPQ) via photoprotective xanthophyll cycling and increased photoprotective carotenoid levels compared to pre-freeze-up. When the ice melted and the cells were exposed to high light, Fv/Fm sharply decreased, while NPQ was less upregulated in low Fe treatments. Interestingly, the psbA gene, encoding PSII reaction centres, was upregulated under high Fe conditions and vice versa. These results suggested Fe availability affects repair rates of the PSII damaged by the high light. Our results indicate that Fe-starved cells were not able to regulate their photosynthetic plasticity to the environmental changes unless Fe was enriched during melting. In conclusion, chronic Fe starvation led to less flexibility of photoacclimation, particularly in low light conditions. This may have detrimental consequences for ice-algal production and trophic interactions if the recent reduction in sea-ice extent continues.

Contrasting phytoplankton communities between Cape Darnley and Dalton Polynyas, off East Antarctica, during sea-ice melting and forming seasons

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Antarctic coastal polynyas are associated with high primary productivity due to proximity to the Antarctic continent and shelf (sources of trace metals to fuel photosynthesis) and long periods of open water (favorable light condition). Different phytoplankton communities are documented for sea-ice zones, which is likely to influence regional biogeochemical cycles (primary productivity and macronutrient drawdown). However, information on species composition including carbon biomass, is limited in coastal polynyas during summer (January to early February) and autumn (late February to early March), when phytoplankton biomass reaches the plateau during a year. We investigated the species composition of phytoplankton from surface water in Cape Darnley Polynya (CDP) and Dalton Polynya (DP), where different values of air-sea CO2 flux are known. We observed high chlorophyll a concentration (up to 3.7 μg/L and 5.6 μg/L for CDP and DP, respectively) during summer, and it remained low in autumn DP (< 1.9 μg/L). In terms of carbon biomass, the predominant phytoplankton was different between the two polynyas. In CDP during summer, diatom (Corethron criophilum) was a major component of phytoplankton carbon (44.5–90.4%). In DP during both seasons, nanoflagellates (Phaeocystis antarctica) and dinoflagellates dominated, accounting for 20.7–98.5%. The ratios of macronutrients (nitrate: phosphate and silicate: nitrate) in water column (0–200 m) were also different between the two polynyas. In CDP, the lower nitrate: phosphate (15.8) and higher silicate: nitrate (1.7) ratios were observed compared to DP, supporting microscopic results that diatoms are more prevailing in CDP. Diatoms with heavy silica frustules are known to have higher export flux than other algal groups (e.g., P. antarctica) due to their rapid sinking. Our results infer that higher air-sea CO2 flux in CDP may be related to diatom predominance.

Bio-optical Depiction of a Polar Ocean Under Global Change: Exploring the Regional Absorption Traits

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The Southern Ocean (SO) is a vital ecoregion crucial in modulating the global carbon cycle and changing climate. Light absorption properties of clear waters are challenging to study due to the very low absorption coefficients typical for these waters, and the SO is no exception. The present study examines the bio-optical variability of light absorption coefficients of phytoplankton and non-phytoplankton constituents during the Indian Scientific Expedition to the Southern Ocean (ISESO) in the austral summer 2017-18. We characterize the light absorption coefficients of bio-optical constituents, quantify their relative contributions to total absorption, derive phytoplankton size classes from two absorption-based approaches, and compare the results with hyperspectral radiometric observations. Our observations suggest a prevalence of the pigment package effect (phenomenon interfering with photosynthetic efficiency of phytoplankton) at both the frontal (40˚S - 60˚S) and coastal (60˚S - 69˚S) domains, inducing deviations from the expected bio-optical classification of the study region. The total light absorption budget indicated a clear dominance of phytoplankton absorption at the frontal (41.93-85.27 %) as well as coastal (36.77-93.71 %) regions. Further, the dominance of microphytoplankton indicated by the aph (443)/aph (675) Blue/Red spectral ratios supported the impact of pigment package on phytoplankton absorption at both, the frontal (0.5-3.2) and coastal (0.9-3.7) regions. The global absorption-based (that links the phytoplankton absorption to their size classes) model captured smaller-sized (pico and nano) phytoplankton better than the larger (micro). A satisfactory agreement was observed between the Quasi-Analytical

Algorithm (radiometer-based) and Quantitative Filter Technique (in-situ measurements) for aph retrieval. The OC5 algorithm of Sea-viewing Wide Field-of-view Sensor (SeaWiFS) was well-correlated with in situ Chlorophyll-a in the region. Our findings improve the existing understanding of bio-optical variability in the SO and highlight the essential considerations that should be taken while assessing the study region through global ocean color platforms. They also highlight the necessity to assess the impact of pigment package on optical variability while designing satellite data tools at a regional level.

Living on the edge: response of deep phytoplankton communities to light, iron and manganese additions

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The Southern Ocean plays a major role in the absorption of anthropogenic carbon dioxide and the regulation of Earth's climate. Part of this process is induced by phytoplankton photosynthesis, transferring carbon from the atmosphere into the ocean. However, Southern Ocean phytoplankton growth is limited by low iron (Fe) and irradiance, impacting the strength of this biological carbon pump. Deep chlorophyll maxima (DCM) can form at depth, where a compromise occurs between nutrient and light conditions. While DCMs are relatively common in the Southern Ocean, they remain under-studied due to their location, and inaccessibility to remote sensing by satellite. To further our understanding on the role of Fe and light in controlling DCMs, we incubated phytoplankton communities from a Southern Ocean polar DCM under increased light and Fe. In addition, we studied the effect of manganese (Mn) additions, an essential micronutrient used in the oxygen evolving complex of photosystem II and in the scavenging of reactive oxygen species.

Results showed DCM phytoplankton communities were primarily light limited. However, this light-limitation did not drive an increase in phytoplankton Fe requirements, as previously suggested. Once light limitation was alleviated, the strongest response was observed under Fe additions which stimulated the growth of large diatoms. The transfer of resident cells to more

optimal conditions (higher irradiance and Fe) led to a major upregulation in their physiology, as evidenced by marked increases in carbon uptake but also chlorophyll, particulate organic carbon, and biogenic silica stocks. Thus, diatoms are probably subsisting in the DCM with sufficient resources in a niche that enables them to continue being productive. However, our results strongly suggest that these cells are also primed for more optimal conditions. In addition, we observed subtle responses to Mn additions, such as community shifts or changes in the bulk carbon uptake. Although these signals were easily hidden by strong responses to Fe additions, they point towards species-specific Mn requirements. These results highlight the need to better understand the role of Mn in controlling Southern Ocean primary productivity, through characterization of the Mn requirements of Southern Ocean species.

Air-sea interactions and climate variability in the Southern Ocean

Impact of a melting 'megaberg' on water column hydrography in the Southern Ocean

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Icebergs impact ocean ecosystems by affecting stratification, nutrient and carbon cycling on regional and basin-scales. With iceberg calving increasing in the last two decades and accounting for half the mass discharge from Antarctic ice sheets, understanding the impact of their fresh, nutrient-rich meltwater is of primary importance. Calved icebergs in Antarctica discharge approximately 1300 km3/yr of freshwater, with the Filchner-Ronne and Ross ice shelves in the Weddell and Ross seas producing 1/3 of the icebergs originating in Antarctica, (Depoorter et al, 2013).

Icebergs are significant as they produce a delayed freshwater release at some distance from source, and can stimulate marine ecosystem productivity through their deposition of terrigenous nutrients in meltwater plumes. This process can promote phytoplankton growth and affect the global cycling of carbon, iron, nitrogen and phosphorous elements. As such, the physical dynamics of iceberg melt rates, pathways from source and entrainment are critical for our understanding of a number of polar and subploar ocean processes.

Here we present results from a targeted deployment around A68 iceberg (~6000 km2), which calved from the Larsen C Ice Shelf in 2017 and moved northeast crossing the Scotia Sea to within 300 km of the island of South Georgia in late 2020, where it subsequently fragmented. An underwater ocean glider was deployed from the RSS James Cook in February 2021 which surveyed the largest fragment in extremely close proximity, measuring temperature, salinity, pressure, chlorophyll and water column turbidity.

We use these glider observations to quantify the impact of iceberg meltwater on the hydrographic properties of the water column, separating iceberg impacts from natural frontal variability by means of a Gravest Emprical Mode technique using historical CTD data. The estimates gained of both deep iceberg melting and surface runoff are compared with mass loss rates derived from satellite data, to better understand the impact of large "megabergs" on upper ocean physics and the Southern Ocean freshwater balance.

High Salinity Shelf Water production in Terra Nova Bay, Ross Sea from high-resolution near-surface salinity observations

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High Salinity Shelf Water (HSSW) is a precursor to Antarctic Bottom Water (AABW), a water mass that facilitates the sequestration of atmospheric heat and carbon into the deep ocean. The salinity of HSSW in the Ross Sea is sensitive to both local and broader regional forcing, with implications for the density of downstream AABW and the ocean's ability to buffer against climate change. One poorly constrained source of HSSW variability in this region is its rate of production within Terra Nova Bay (TNB) in the western Ross Sea. Here, we use an unprecedented set of near-surface salinity, current velocity, and acoustic surface tracking timeseries, collected from a mooring in TNB in austral winter 2017, to estimate HSSW production rates. In one of few studies at the resolution of individual katabatic wind events, we find that HSSW production rates correlate with katabatic wind event frequency in early winter and with frequency, strength, and duration in late winter, suggesting a complex dependence on polynya dynamics. We calculate an average HSSW production rate of ~0.6 Sverdrups (10^6 m^3 s^(-1)) that allows us to validate an approach for estimating production rates from parametrized net surface heat fluxes, which we use to examine interannual variability in production rates across the decade. Though further mooring-based estimates are needed for confirmation, results suggest HSSW production in TNB has been mostly increasing since 2015 and could play a previously unrecognized role in the recently observed recovery of HSSW salinity in this region.

Long term spatiotemporal trends in chlorophyll-a and sea surface salinity in Southern Ocean and their association with aerosol nutrients

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Aerosols over the oceanic region play a significant role in Earth's energy budget and climate change. This study examines the spatiotemporal patterns of MODIS retrieved Aerosol Optical Depth (AOD), Sea Surface Temperature (SST), Chlorophyll-a (Chl-a) along with MERRA-2 retrieved dust mass concentration over the Southern Ocean (60o S–90o S to 0o E–360o E) during 2002 – 2023. The Southern Ocean is the most vulnerable to global climate change as it warms quickly. Annual average SST is observed to be ~4o C around Scott and Peter Island. Highest chl-a concentration (~1.2 mg m-3) was observed along the coast of the Ross Sea. A wind-driven ocean gyre dominates the circulation of the Ross Sea, and the flow is strongly influenced by three submarine ridges that run from southwest to northeast. The circumpolar deep-water current is a relatively warm, salty, nutrient-rich water mass flowing onto the continental shelf at certain locations. An abundance of plankton was supported by the nutrients. The value of AOD is observed to be ~1.8 around Scott Island as it is a volcanic-prone island. Dust mass concentration of ~11.92 kg m-3 was observed in the northwestern region.

High-resolution thermal imaging in the Antarctic Marginal ice zone: Ocean skin heterogeneity and effects on heat fluxes

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The Southern Ocean has the capacity to store and release more energy than any other latitude band on the planet and, hence, it is a major contributor to global climate. At high latitudes, energy fluxes are mediated by a strong seasonal sea ice cycle, which forms and unsteady composite interface of different types of sea ice and open water fractions, separating the upper ocean from the lower atmosphere.

The general lack of in-situ observations in the sea ice region hampers the understanding of relevant mechanical and thermodynamic processes, resulting in uncertainties of satellite observations, prediction models and reanalysis product.

Here we present high-resolution thermal images of the ocean surface from infrared sensors installed aboard the icebreaker S.A.~Agulhas~II during winter and spring expeditions.

Data revealed a structured distribution of different sea ice types with neat demarcations but strong thermal gradients in the winter. A comparison with ERA5 reanalysis indicates uncertainties in the estimate of the skin temperature, which are attributed to errors in sea ice concentrations and are a source of discrepancies in energy fluxes. In spring, the sea ice regions is disordered with alternation of sea ice fractions and large opening even 400~km from the ice edge. The thermal footprint of the ocean skin is homogeneous and it does not produce relevant uncertainties in energy fluxes, despite errors in the sea concentrations. Uncertainties in spring are linked to biases in the downwelling solar radiation.

Water mass and heat flux exchanges between the Southern Ocean and Antarctica seas, East Antarctica

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Hydrographic top-to-bottom CTDs and profiling float profiles were collected during 2003-2020 periods in the south-west Indian Ocean sector of the Antarctic margin. Those calibrated dissolved oxygen, temperature and salinity records were used to document the distribution, pathway and changes of the newly-formed Cape Darnley Bottom Water (CDBW) and the recent changes of circumpolar deep water (CDW). Recent changes of CDW were dominated by the southern Antarctic Circumpolar Current Front (sACCF) shift due to the enhanced northwest summer winds. The newly-formed CDBW presented showed significant cooling, freshening, and increasing dissolved oxygen rates on the continental slope just off CDP. The Sea Ice Production (SIP) in the Cape Darnley Polynya (CDP) shows significant increasing trends during 2002-2020, which indicates an increased formation of regional DSW driven by the sea-ice formation and associated brine rejection, thus increasing formation of CDBW.

ACC Meanders Enhance Air-Sea Heat Flux Exchange and Water Subduction

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Standing meanders along the Antarctic Circumpolar Current (ACC) host strong ocean dynamics and enhance cross-front exchange. Air-sea heat fluxes, mixed layer depth (MLD) and three-dimensional velocity outputs from high resolution simulations show variability at the scale of meanders and related small-scale processes. In this study, we diagnose surface heat fluxes as well as water mass subduction along the ACC from 120°E to 165°E in the 1/10° ACCESS-OM2 ocean model forced with the JRA55 atmospheric reanalysis. We also track the model's Subantarctic Front and Polar Front based on water mass properties. The thermodynamical and dynamical properties are compared to the position and flexing of the ACC fronts in the region.

The results reveal that a standing meander south of Australia substantially changes the distribution of surface heat fluxes, mixed layer depth and subduction of water below the permanent mixed layer. Upwelling (downwelling) modulates the heat gain (loss) at the trough (crest) of the meander. This pattern is reflected in the MLD and lateral induction of fluid below the thermocline. We link the stretching and thinning of the mixed layer to the air-sea heat fluxes. The deepening of the MLD at the crest is intimately linked to the regions of heat loss by the ocean at the crest of the meander. The opposite occurs at the trough. Heat loss is equivalent to buoyancy loss (or density gain) that causes the deepening of the MLD. Otherwise, the heat gain at the trough results in the shallowing of the MLD.

Finally, the difference in composites of a relaxed and flexed Polar Front meander show a link between the meander flexing, heat fluxes and water subduction. Clarifying the nature of these features contributes to understanding how localized standing meanders control the air-sea heat fluxes across the Southern Ocean as well as the ventilation of the ocean interior (i.e., uptake of anthropogenic heat and carbon).

Summer upper ocean warming controlled by storms in the subpolar Southern Ocean

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The ocean plays a crucial role in absorbing excess heat from the atmosphere, with as much as 93% of this heat being absorbed by the ocean. However, there is still much uncertainty surrounding the scales at which mechanisms drive air-sea heat exchange, particularly in the Southern Ocean, where an estimated 75% of oceanic heat uptake occurs. This study focuses on the ocean's thermal response to synoptic-scale atmospheric cyclones and investigates whether internal ocean variability is important in understanding air-sea interactions. Using data collected during a three-month deployment of a Slocum glider in the polar upwelling region of the Atlantic Southern Ocean, this study finds that synoptic-scale events, characterized by intense winds and enhanced friction velocity, play a significant role in maintaining a deep mixed layer depth and slowing down the ocean surface warming rates during the summer. Only during a six-day lull in the winds when the impact of storm-driven mixing is abated does the stratification within the mixed layer increase. During this time, a mean heat flux of 180 W m-2 led to the mixing layer depth shoaling by approximately 40 meters. This subsequent change in the oceanic mixed layer depth resulted in a mixed layer warming rate consistent with observed sea surface temperature biases in climate models. This finding suggests that strong winds linked to Southern Ocean storms are critical in understanding summertime warming of the oceanic mixed layer. It highlights the importance of accurately representing storm density and intensity in weather and climate models.

Storm's role for air-sea CO2 exchange in the Southern Ocean

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The strength of the Southern Ocean as a carbon sink is uncertain, particularly in the wintertime when models and observations disagree. Extratropical storms often mix and cool the upper ocean, with consequences for biogeochemistry and thus, air-sea carbon dioxide (CO2) exchange. Here, we track storms using atmospheric sea level pressure fields from reanalysis data to assess the role that storms play in driving air-sea CO2 exchange, examine main drivers of CO2 fluxes under storm forcing, and quantify their contribution to regional annual air-sea CO2 fluxes. We use a forced ocean run of the Community Earth System Model, as well as CO2 fluxes derived from Biogeochemical Argo floats. We find that storms induce CO2 outgassing that is an order of magnitude larger in observations compared to the model and is caused by different physicochemical mechanisms induced by storm forcing. While CO2 outgassing in the model is entirely driven by the reduction in atmospheric pressure associated with cyclonic systems, Argo float observations indicate a larger role of non-thermal effects on seawater CO2 partial pressure through entrainment of dissolved inorganic carbon from enhanced upper ocean mixing. Despite large uncertainties in CO2 flux and storm statistics, observations suggest a pivotal role of storms in driving Southern Ocean air-sea CO2 outgassing that needs to be better represented in Earth System models to constrain air-sea CO2 exchange in the Southern Ocean and future climate projections.

An ensemble-based Data Assimilation System for the Southern Ocean (DASSO)

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To improve Antarctic sea-ice simulations and estimations, an ensemble-based Data Assimilation System for the Southern Ocean (DASSO) was developed based on a regional sea ice–ocean coupled implementation of MITgcm and the parallel data assimilation framework (PDAF), which assimilates sea-ice thickness (SIT) together with sea-ice concentration (SIC) derived from satellites. The result of experiments conducted from 15 April to 14 October 2016 shows that assimilating SIC and SIT can suppress the overestimation of sea ice in the model-free run. However, a covariance inflation procedure is required in data assimilation to improve the simulation of Antarctic sea ice, partially due to the underestimation of atmospheric uncertainties.

Thus, a multivariate balanced atmospheric ensemble forcing is further developed for DASSO based on the high-resolution ERA5 reanalysis, which considers the relationship between different variables and adjacent times. The model-free run of 2016 shows that this newly generated atmospheric ensemble forcing can suppress model errors of SIC and produce better estimates of simulation uncertainties. Further analysis reveals the improvement stems from a better representation of atmosphere-ocean and sea ice-ocean thermodynamic processes in the model. This makes it possible to improve the background error estimate of DASSO.

Based on this improvement, the observation error estimate and the localization scheme are further optimized for DASSO. The preliminary result of the long-term data assimilation experiments shows that compared with our initial configuration, optimized DASSO can better reproduce the

condition of Antarctic sea ice and decrease reliance on the covariance inflation procedure significantly. Along with more Antarctic sea ice observations due to be released soon, the prospects look bright for reconstructing long-term Antarctic sea ice conditions, especially SIT and volume, through sea-ice data assimilation.

Circumpolar Antarctic Ice Sheet-Ocean observations: towards an integrated view and improved climate models – Part 1

Antarctic RINGS to characterise the Antarctic Ice Sheet coastal zone and Antarctica's contribution to sea-level rise

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Regions where the Antarctic Ice Sheet reaches the coast are fundamental to our understanding of the interactions between Antarctica and the global climate system. Coastal regions are where tipping point thresholds may be exceeded for the Antarctic Ice Sheet in the ongoing 2 degree C warming world, and these regions must be better understood to predict future sea-level rise. The Antarctic Ice Sheet constitutes the largest source of uncertainty in future sea-level projections, and this uncertainty is mainly rooted in poorly known bed topography under the ice sheet; bed topography matters the most in the coastal regions as it controls the stability of the ice sheet. Together with an overview of the current multidisciplinary understandings of the Antarctic coastal regions, we present ensemble analysis of published datasets to present data and knowledge gaps, and their regional distribution is discussed in the context of ice-sheet evolution and instability. Finally, we identify outstanding science priorities and discuss protocols of airborne surveys to develop a comprehensive dataset uniformly all-around Antarctica.

NECKLACE: Collating a circum-Antarctic dataset of ice shelf basal melt

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Ocean-driven melt at the base of floating ice shelves is a major mass loss process from the Antarctic ice sheet, and a key component in accurately predicting its contribution to future sea level rise. Observations of basal melt are important tools for testing and improving models of ice shelf-ocean interaction. While many of these observations come from satellite methods, field observations of melt are valuable for validating satellite-derived data products, and to provide higher-temporal resolution timeseries of melt.

The NECKLACE project aims to collate field measurements of ice shelf melt to create a standardised data product that can be used by glaciologists, oceanographers, and ice sheet modellers for testing and validation. Field measurements of melt can use a range of techniques, including range finding from under-ice moorings and surface radar instruments, but the most commonly used instrument in recent years is the Autonomous phase-sensitive Radio Echo Sounder (ApRES) due to its low cost and ease of deployment. The project will combine data contributions from multiple international teams to create a continent-wide, open-access database of timeseries of basal melt rates. The initial dataset is likely to gather contributions from over 40 sites on 12 ice shelves. Beyond the collation of existing data, the project team also aims promote the collection of new field data by providing assistance with equipment procurement, set-up, and data processing. We hope that this data product can provide the basis for an ongoing monitoring network observing basal melt around Antarctica, and an important data source for assimilation into regional ocean models.

Western Ross Sea ice tongues sentinels of oceanographic change

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Antarctica has been losing mass at an accelerating rate. Basal melt and calving of the floating portions of the ice sheet are the main mechanisms of ice loss. Here we focus on one of the stable regions of Antarctica, the Western Ross Sea. Using remote sensing tools, we look into the stability mechanisms contributing to ice tongue prevalence in the region. The oceanographic conditions in the Western Ross Sea are influenced by a cold coastal current originated in the Ross Ice Shelf cavity with added sources along the Victoria Land Coast. We proposed that this coastal current promotes the stability of the ice tongues in the region by maintaining low basal melt rates and encouraging land-fast sea ice (fast ice) growth. Here we present the basal mass balance of 12 ice tongues and show the effect of fast ice over ice tongue dynamics and mechanics using two case studies.

Using a flux gate approach, we calculate the basal mass change of twelve Antarctic ice tongues, deriving thickness from ICESat-2 height measurements and ice surface velocities from Sentinel-1. The basal mass balance ranges between -0.14 ± 0.07 m yr-1 and -1.50 ± 1.2 m yr-1. The average basal mass change for all the ice tongues is -0.82 ± 0.68 m of ice yr-1. Low values of basal melt suggest a stable mass balance condition in this region, with low thermal ocean forcing. We found a heterogeneous basal melt pattern with no latitudinal gradient and no clear driver in the basal melt, indicating that local variables are important in the persistence of ice tongues without a strong oceanographic melting force.

We found that fast ice can influence the dynamics and mechanics of ice tongues, promoting growth and hindering calving when present. The fast ice influence over ice tongues was observed by studying an unprecedented calving event over the Parker Ice Tongue and the lateral flexure of the Erebus Ice Tongue. Before the Parker Ice Tongue calving, we observed that during the short summer period, characterised by decreased fast ice extent, the ice tongue showed around 11% higher velocities than in winter. While the lateral flexure study done over the Erebus Ice tongue indicated that the average flexure of the ice tongue was two times higher (0.44m) when fast ice was absent (34.7% of the time) than when embedded in fast ice (0.19m). It also presented a significant correlation (0.45) between flexure and tidal currents found when fast ice was absent.

Due to the unconfined nature of Ice tongues, we highlight the vulnerability of the ice tongue once exposed to oceanic processes. We concluded that fast ice persistence enhances ice tongue growth, delays ice tongue calving and acts as a protective mantle against ocean erosion and tidal forcing. Therefore, what will be the fate of such magnificent features with future changes in fast ice cover and ocean conditions?

Subglacial freshwater drainage increases simulated basal melt of the Totten ice shelf

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Subglacial freshwater discharge from beneath Antarctic glaciers likely has a strong impact on ice shelf basal melting. However, the difficulty in directly observing subglacial flow highlights the importance of modelling these processes. We use an ocean model of the Totten Ice Shelf cavity into which we inject subglacial discharge derived from a hydrology model applied to Aurora Subglacial Basin.

Our results show (i) discharge increases melting in the vicinity of the outflow region, which correlates with features observed in surface elevation maps and satellite-derived melt maps, with implications for ice shelf stability; (ii) the change in melting is driven by the formation of a buoyant plume rather than the addition of heat; and (iii) the buoyant plume originating from subglacial discharge-driven melting is far-reaching.

These results highlight the importance of subglacial hydrology and plume dynamics for ice shelf stability, which are features lacking in almost all ice-ocean models. Further, these findings emphasize the need to incorporate these dynamics in large-scale ice-ocean models in order to better understand and predict the stability of Antarctic ice shelves in a warming climate.

Seafloor roughness reduces melting of the Antarctic ice sheets

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The Antarctic ice sheet melting is driven primarily by the ocean circulation, transporting warm CDW from the Southern Ocean, onto the continental shelf, and towards the ice shelf cavities. Projections of the ice sheet melt rate are based on the ocean thermal forcing derived from global climate models, which tend to be bias warm in the ocean around Antarctica. The bias has been partly attributed to unresolved ocean processes, some of which are generated by seafloor roughness, poorly represented in climate models. Here we show, using a high-resolution model of the Denman Glacier region, that the seafloor roughness suppresses the impact of CDW on the ice sheet melting. It acts as a drag on the ocean circulation, reducing its kinetic energy and hence the volume of CDW present over the shelf. As a result, the ice sheet melt rate decreases by 15% (4 Gt/year). Our results suggest that the seafloor roughness enables a negative feedback that has the potential to reduce the uncertainty of sea level projections.

Internal tsunamigenesis and ocean mixing driven by glacier calving in Antarctica

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Ocean mixing around Antarctica exerts key influences on glacier dynamics and ice shelf retreats, sea ice, and marine productivity, thus affecting global sea level and climate. The conventional paradigm is that this is dominated by winds, tides, and buoyancy forcing. Direct observations from the Antarctic Peninsula demonstrate that glacier calving triggers internal tsunamis, the breaking of which drives vigorous mixing. With such calving being widespread and frequent, these internal tsunamis are found to be at least comparable to winds, and much more important than tides, in driving regional shelf mixing. They are likely relevant everywhere that marine-terminating glaciers calve, including Greenland and across the Arctic. Calving frequency may change with higher ocean and air temperatures, suggesting possible accelerations of internal tsunamigenesis and mixing in a warming climate.

ORAL ABSTRACTS

Sea ice – ocean – land ice: interacting processes in the western Ross Sea observed by airborne geophysics

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Antarctic sea ice is a stabilizing factor for global climate. But, as sea-ice thickness is particularly difficult to measure, it has an unknown mass trend. The western Ross Sea is an important region of sea-ice formation, where one distinguishing sea-ice process is the regular occurrence of the Ross Sea, McMurdo Sound, and Terra Nova Bay polynyas. At the same time, sea ice in this region is close to ice sheets and ice shelves, and the outflow of Ice Shelf Water favours the formation of land-fast sea ice with a sub-ice platelet layer (SIPL) beneath. Sea ice in this region grows to above-average thickness.

Using airborne electromagnetic induction surveys, we provide a direct glimpse of late spring sea-ice thickness distribution in the western Ross Sea between McMurdo Sound and Cape Adare. Two flights in November 2017 over a length of 800 km reveal a heavily deformed pack ice regime with a mean thickness (including snow) of 2.0 ± 1.6 m. Additional flights over a length of 700 km have been conducted over land-fast sea ice providing a first-time inventory of fast ice thickness close to its annual maximum. The overall mode of the consolidated fast-ice thickness was 1.9m.

Supported by satellite image analysis, we identify regional variability in pack-ice thickness based on formation history. Sea-ice thickness gradients are highest within 100 and 200 km of the Terra Nova Bay and McMurdo Sound polynyas, respectively, where the mean thickness of the thickest 10% of ice is 7.6 m. Overall, about 80% of the pack ice was found to be heavily deformed, concentrated in ridges with thicknesses of 3.0–11.8 m. This is evidence that sea ice is much thicker than in the central Ross Sea.

Our analysis over fast ice was partitioned into level and rough ice, and SIPL thickness was estimated under level ice. Rough ice occupied 41% of the transect by length, 50% by volume. The thickest 10% of rough ice was almost 6 m on average. The thickest ice occurred predominantly along the northwestern Ross Sea, due to compaction against the coast. The adjacent pack ice was thinner (by ~1 m) than the first-year fast ice. In general, the SIPL volume was a significant fraction of the consolidated ice volume, implying vigorous heat loss to the ocean at many places. We conclude that polynya-induced ice deformation and interaction with continental ice influence fast ice thickness in the western Ross Sea.

A connected circulation system of the West Antarctic shelf seas

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Both observational and modeling studies have greatly expanded our understanding of the physical processes, which span the shelf break to the Antarctic coast, control the transport of warm Circumpolar Deep Water across the continental shelf and under floating ice shelves. Yet, most of these studies have focused on regional dynamics within individual shelf seas. More recent studies have shown that coherent boundary currents, such as the Antarctic Slope Current and the Antarctic Coastal Current, connect neighboring shelf seas and contribute to setting broad-scale hydrographic and biogeochemical properties even in response to remote forcing perturbations. This talk will highlight observations and numerical models, predominantly in the western Bellingshausen Sea, that have elucidated key transport pathways that enable inter-sea exchange in West Antarctica. Both observations and tracer release numerical experiments show that meltwater from different ice shelf sources can be distinguished by their optical properties (backscatter) as well as their density horizon. The injection of meltwater at different density levels impacts transport pathways and residence times of these modified water masses over the continental shelf, especially due to recirculation in major troughs. Freshwater anomalies due to the input of glacial meltwater modify both vertical and lateral stratification of the water column, which impacts vertical and lateral heat fluxes that control heat transport into heat transport into ice shelf cavities and ice shelf basal melt rates. Finally, offshore variability, specifically related to wind forcing of the Ross Gyre, is shown to have a broad impact on cross-slope and cross-shelf heat transport throughout West Antarctica. Together, these results indicate that small changes in not only the volume flux of glacial meltwater, but also its ice shelf provenance and density properties, can have climatically important feedbacks that influence the large-scale circulation of the West Antarctic shelf seas and future rates of ice shelf melt. Many of these processes occur at spatial and temporal scales that are poorly resolved by current climate prediction models.

Poleward transport of mCDW mediated by standing eddies in Southern Ocean Indian Sector

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Warm mCDW is a major cause of ice shelf basal melting leading to mass loss in the Antarctic ice sheet. The mCDW has been observed beneath the ice shelf, but the processes and mechanisms by which mCDW, which originally resides in ocean basins, is transported to Antarctic coastal regions and ice sheets are unclear. We have initiated a research project "Heat-Cross" to investigate the transport of mCDW, especially around Totten Ice Shelf, using field observations, satellite observations, and numerical modeling. This project started when we found scattered standing oceanic eddies in the Southern Ocean Indian Sector from our analysis of satellite altimeter data. It has become clear that the standing oceanic eddies transport warm mCDW from the ocean basins to the continental shelf slope. The standing oceanic eddies, located offshore of Totten Ice Shelf, contributes 2.6-11 TW of heat transport. Of course, not all of this heat is directed to Totten Ice Shelf, and there is undoubtedly some heat loss on the continental shelf. At this point, in discussing the contribution of the oceans to ice sheet loss, it is necessary to clarify the " the process of eddy formation and maintenance and the factors that cause fluctuations in its circulation", "ocean circulation on the continental shelf" and "seasonal and interannual variations in heat transport from ocean basins to the continental shelf slope and from the continental shelf slope to the ice shelf and their factors". Here, we introduce the results of our field observations by the icebreaker "Shirase" and the training ship "Umitaka-maru" and discuss our future research plans on mCDW transport.

Southern Ocean plankton: productivity, diversity, food-web dynamics, time-series & biogeochemistry / Processes and ecosystem response of the Southern Ocean

Subantarctic and Antarctic Peninsula Sediment Trap Water Soluble Organic Matter Characterization: Insights from Ultrahigh Resolution Mass Spectrometry

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The Southern Ocean plays a disproportionate role in global carbon (C) sequestration, critically regulating the Earth's climate. This has largely been attributed to the intensive phytoplankton-mediated fixation of atmospheric $CO2$ into particulate C with subsequent storage in the deep ocean, known as the Biological C Pump (BCP). The BCP involves multiple pathways of C export including sinking particles, subduction of dissolved and particulate organic C, and active transport mediated by vertically migrating organisms. The depths at which particles are remineralized, largely by marine microbes, determines the C sequestration time from the atmosphere. Considering microbial-plankton interactions transform ~50% of the particulate organic matter (POM) to dissolved organic matter (DOM) in the upper mixed layer, we also need to consider how the molecular partitioning of this DOM into labile and refractory pools is shaping C sequestration in the Southern Ocean. Microbial remineralization of POM is a

selective process where the microbial release of exoenzymes preferentially cleaves specific molecule classes from the sinking POM, enriching the abundance of DOM in the surrounding water that bacteria take up through cell membranes. Here we molecularly characterize the water-soluble organic matter (WSOM) fraction associated with sinking POM from sediment traps in the Subantarctic and Antarctic Peninsula utilizing the extreme mass accuracy and precision of ultrahigh-resolution Fourier-transform ion cyclotron resonance mass spectrometry. The molecular-level characterization of the WSOM fraction of sinking POM is a function of the upper mixed layer biogeochemical environment (e.g., abundances of diatoms or prymnesiophytes and higher trophic level zooplankton) as well as the solubilization factors and microbe-POM interactions throughout the water column. Preliminary POM data describes a 3 to 8-fold increase in Subantarctic C sinking fluxes where zooplankton abundances were high, coinciding with elevated C:N ratios (6.1 to 9.7; mol:mol) and an increase in the BCP efficiency. These fluxes and C:N ratios are comparable to those calculated for the Antarctic Peninsula during relatively high zooplankton abundances. Further, while the molecular-level characterization of WSOM describes expected trends of rapid remineralization of biolabile compounds (including aliphatics, energy-rich compounds) and persistence of refractory DOM compounds at depth, the molecular characterizations of deep samples (between 300 – 500 m) associated with high upper mixed layer zooplankton abundances are observed to have a 2 to 3-fold relative abundance of aliphatic molecules. This suggests rapidly sinking POM escaping mixed layer remineralization and driving a strong BCP that introduces a potentially large labile DOM pool to the Southern Ocean at depth. These findings are unique and are not observed at other highly productive regions, such as the California Current upwelling system. The large variability in productivity regimes, taxonomic composition and abundance of organisms, and types of sinking particles makes this Southern Ocean regional comparison a unique approach in better understanding and constraining the BCP. Further, we plan to contextualize these findings against the backdrop of a global dataset including high productivity upwelling regions and low productivity oligotrophic regions to better understand how global climate change can alter Southern Ocean biological C sequestration.

Has the calving of the Mertz Glacier Tongue affected zooplankton community structure in a region of variable fast ice?

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In Antarctica, fast ice is a key component of the coastal ecosystem that highly variable in space and time. This has important implications for the wider Antarctic coastal ecosystem, due to the dependence of many species on fast ice for habitat and food provisioning. The calving of the Mertz Glacier Tongue (MGT) in February 2010 is one example of the highly dynamic nature of the fast ice environment. However, the effects of this event on the local biology – specifically zooplankton community structure – is poorly understood. This study investigated changes to the physical environment and to the zooplankton community structure before and after the calving event and aimed to identify any links between environmental controls and zooplankton community assembly. Zooplankton samples collected between 2000 and 2017 were assessed to identify any changes in community structure following the calving. Meteorological data were obtained via European Centre for Medium Range Weather Forecasts Reanalysis 5th Generation (ERA5) hourly records. These variables included 10-metre zonal (u) and meridional (v) wind components and surface pressure, and were used to identify any changes to surface pressure or wind speed and direction during the study period that may have contributed to the observed changes in zooplankton community structure and fast ice extent. A significant difference in the zooplankton community structure between the two periods was detected, and zooplankton abundance also increased steadily in the decade following the calving of the MGT. It was found that winds typically blow from the southeast in the region, however, a storm in February 2010 was found to predominantly blow from the northeast, which may have contributed to the build-up of fast ice following the calving event. This meant that the region was then occupied by perennial sea ice, which likely drove a shift in the zooplankton community structure and may also have facilitated the observed increase in zooplankton abundance. The eventual break-up of the perennial ice in 2015 was followed by a large increase in zooplankton diversity. Overall, these results indicate a clear relationship between the fast ice environment and the zooplankton community structure in the region.

Using novel methods to detect ecological changes in species communities of the Southern Ocean.

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In the last 50 years, the Southern Ocean has been facing a rapid shift in environmental conditions and ecology due to anthropogenic pressures, including climate change. These environmental changes are likely influencing the distribution and abundance of zooplankton communities. Due to the complexities associated with zooplankton communities and their ecology, they are difficult to monitor for detecting changes at the community level. To simplify the process and to focus on finding novel methods of detecting ecological changes in the species communities of the Southern Ocean, we focused on the euphausiid (krill) community as they are the most studied group of zooplankton taxa in this region. While some krill species have been extensively studied, we still lack information about the distribution of many non-endemic krill species and their interactions as a community. We used the long-term and extensive SO-CPR (Southern Ocean-Continuous Plankton Recorder) data set as the basis for simulating virtual krill communities to examine the effects of species and community attributes, data characteristics and statistical methods under various climate change scenarios. Simulations utilised prevalence and abundances, species interactions and responses to key environmental factors that were based on those observed and then modified to test a range of climate change scenarios. By successfully detecting changes in the virtual krill communities, this approach could be applied to detecting real-world changes in the krill communities of the Southern Ocean.

Long-term continuous plankton recorder data and joint species distribution models reveal changes in zooplankton communities in the Southern Ocean

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Zooplankton are an integral part of the marine ecosystem, providing a pathway of energy transfer from primary producers through to fish, seals, and birds. The Southern Ocean is a highly productive and dynamic system supporting diverse communities of zooplankton. The Antarctic research community has been monitoring zooplankton using the standardised continuous plankton recorder to collect assemblage data for many decades. To date the bulk of the analysis on CPR data has focussed on krill. In this study we use 20 years of CPR data with joint species distributions models to study the entire species assemblage and establish where, when and what species have changed in prevalence and abundance. Specifically, we use hierarchical modelling of species communities to model the presence/absence and abundance of each species as well as total zooplankton abundance and species richness in relation to environmental and climate variables. We demonstrate that the distribution of zooplankton and community structure is highly complex, patchy, and susceptible to rapid change due to rising sea surface temperatures, changing ocean currents, and the southern annular mode. We show that while many species have actually increased in prevalence and abundance, a number of species have declined. The ecological consequences for this change in community structure is unknown. This study highlights the importance of having long-term monitoring data using the standardised methods such as the

CPR. The results from this study will be used to further explore which species and where future monitoring efforts should focus in order to maximise the efficiency of zooplankton monitoring but it needs to be spatially balanced across the Southern Ocean to enable the ability to detect future change.

The Influence Of Feculence: Swimming Behaviour and Grazing Rate Changes Of Antarctic Krill (Euphausia Superba) In The Presence Of Guano

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Predation has long been implicated as a major selective force in the evolution of morphological and behavioral characteristics of animals. The importance of predation during evolutionary time is clear, but growing evidence suggests that animals also have the ability to assess and behaviorally influence their risk of being preyed upon in ecological time. Antarctic krill (Euphausia superba) are a key component of the Antarctic ecosystem linking primary and some secondary production to higher trophic levels including fish, penguins, and whales. This study looked at the influence of penguin guano, as a proxy for a nearby predator and a negative chemical stimulus, on: krill swimming behaviour and kinematics in a horizontal flume and on krill ingestion, grazing and feeding rates. Krill had a higher frequency of acute turns when guano was present meaning they were unable to maintain a heading. Krill also varied their swimming speeds more when guano was present, showing a distinct pattern of bimodal swimming. These are both indicators of avoidance behaviour to the negative chemical cues represented by penguin guano. Similarly, krill's ingestion rates significantly dropped in the presence of guano, even with an increase in algal density. This study has shown for the first time that the presence of a negative chemical stimulus as a proxy for a predator, such as guano, can not only dampen the feeding rates of krill but it can make them exhibit clear avoidance swimming behaviour as well.

Long term monitoring of Southern Ocean plankton using the Continuous Plankton Recorder program

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The continuous plankton recorder (CPR) survey was designed by Sir Alister Hardy in the 1920's as a means to monitor the eggs and larvae of key fish stocks in the North Sea. Since its inception, it has now been used to consistently map plankton distribution over spatial and temporal scales. Data acquired from CPR tows can be used to understand fisheries recruitment, inform fishing effort, document changes in plankton communities linked to environmental conditions, and inform decision makers on the management of marine areas. For Australian plankton research, the CPR is deployed on 'Ships of Opportunity' (volunteer, commercial and research vessels used by the Integrated Marine Observing System (IMOS) to collect physical, environmental, chemical and biological marine data). Zooplankton sampling for the Southern Ocean is performed by the Australian Antarctic Division (AAD), and in conjunction with phytoplankton sampled through IMOS, this forms the Southern Ocean Plankton Survey (SO-CPR) program. The SO-CPR program samples the Southern Ocean from 47 °S southward to the Antarctic ice edge, with plankton records for the Southern Ocean and sub antarctic dating back to 1990. This provides a 30 year window into the composition of plankton communities, including the possible trends and shifts of communities throughout the Southern Ocean as the oceans warm. In this study, we used the SO-CPR program to map and track zooplankton and phytoplankton communities in the Southern Ocean and sub antarctic across this 30 year period. We discuss the changes to the community dynamics across this time period, and the continued development of the SO-CPR program. This study demonstrates the applicability and strength of long-term data sets in the Southern Ocean, and discusses the advantages and limitations of the Southern Ocean continuous plankton recorder program.

Up, down, and sideways: Antarctic krill (Euphausia superba) swimming behaviour in differing flow, light and chemical cue conditions

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Antarctic krill (Euphausia superba) are a key component of the Antarctic ecosystem and an important commercial species. However, their behavioral responses to relevant environmental stimuli such as flow direction and velocity, light and chemical cues, remain poorly known. This limits our understanding of krill habitat choice and demography, as well as how aggregation structure reflects changes in swimming behavior of individual krill. To close this gap, we exposed adult krill to controlled horizontal (0.1-10 cm s-1) and vertical (upwelling and downwelling; 1-3 mm s-1) flows in differing combinations of light intensity (surface vs. 100 m ambient light) and food cues (ambient, early bloom, full bloom conditions as inferred by chlorophyll a). Krill respond to flow speed, direction, and their interactions. Slow horizontal flows polarize krill orientation and direction in the up-current direction. Low-moderate chlorophyll levels enhance this behavior, while high chlorophyll levels paradoxically increase turning and down-current movement. Krill fail to hold station at high current speeds even in high chlorophyll levels. Krill respond to downwelling (but not upwelling) flows in the same manner as horizontal flows by directing swimming against the flow while also changing body angle. There was no consistent effect of light.

Impacts of recent Antarctic Sea-Ice Extremes

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Antarctic sea ice has experienced five extreme events in the last decade: three record lows, and two record highs. These extreme sea ice events have wide ranging impacts on the ocean, other cryospheric components, and the Southern Ocean ecosystem as well as far field repercussions. Extreme low summer sea ice results in an increased loss of multiyear fastice, increases in coastal exposure and changes the seasonality of the sea-ice cycle. Surface ocean warming during the summer is observed due to the ice-albedo feedback, resulting in changes to the rate of watermass transformation. We find that ice-shelf calving is correlated with sea-ice area, so that years with less sea ice show increased calving. Within the annual cycle, prolonged open water affects the seasonality of surface phytoplankton blooms. In addition, changes to the sea-ice seasonal cycle alter the input of iron from melting sea ice, subsequently modifying primary productivity. Under-ice algae are strongly affected by changes to the sea-ice coverage, and years with less ice show substantially reduced under-ice primary productivity. The impacts on higher trophic levels are complex, but include habitat loss and impacts on prey availability. The loss of coastal fast ice in the summertime causes logistical challenges for Antarctic fieldwork and resupply missions for Antarctic research stations. Changes in the sea-ice and fast-ice seasonality as well as in the physical properties of the ice have profound effects on coastal and ice-infested water operations, requiring increased observations and analysis of the ice conditions. Changing accessibility of the Southern Ocean may lead to renewed tensions around Antarctic treaty negotiations.

Understanding the full impacts of recent, and future, sea ice extremes requires a broad observational network that spans the physical and ecological systems of Antarctica and the Southern Ocean.

Spatiotemporal variability of dissolved inorganic macronutrients along the northern Antarctic Peninsula

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The northern Antarctic Peninsula (NAP) is a key region of the Southern Ocean due to its complex ocean dynamics, distinct water mass sources, and the climate-driven changes taking place in the region. Despite the importance of macronutrients in fuelling primary production and driving the strong carbon uptake and storage, little is known about their spatiotemporal variability along the NAP. Hence, we explored an austral summertime oceanographic database spanning 24-year in this region. The database results primarily from the Brazilian High Latitude Oceanography Group (GOAL) continuous efforts to understand the processes involved in the spatial, seasonal and interannual variability of macronutrients in the NAP. We found high macronutrients concentrations in all NAP environments, even in surface waters and coincident with strong phytoplankton blooms. Minimum concentrations of dissolved inorganic nitrogen (DIN) (16 µmol/kg), phosphate (0.7 µmol/kg), and silicic acid (40 µmol/kg) along the NAP are higher than those recorded in surrounding regions. The main sources of macronutrients are the periodic intrusions of modified Circumpolar Deep Water (mCDW), which is enhanced by local sources, such as organic matter remineralisation, water mass mixing, and mesoscale activity. Nevertheless, we identified a depletion in silicic acid in the central basin of Bransfield Strait due to the influence of Dense Shelf Water (DSW) from the Weddell Sea. Macronutrient concentrations show substantial interannual variability driven by the balance between the intrusions of mCDW and advection of DSW, which is largely modulated by the Southern Annular Mode and to some extent by the El Niño-Southern Oscillation. In addition, we found uptake ratios of DIN/phosphate less than 16 and silicic acid/DIN greater than 1, which are commonly associated with high phytoplankton biomass, mainly composed of diatoms. Moreover, those microalgae communities have been linked to strong carbon dioxide uptake in the coastal and relatively shallow zone of the NAP. Despite the enhanced summer phytoplankton growth, relatively low seasonal nutrient drawdown was found in most sub-regions of the NAP, approaching near-zero drawdown for phosphate and silicic acid. This is likely due to the high supply of macronutrients from different sources, which makes NAP environments highly favourable for growth and development of phytoplankton blooms. This is particularly important as the NAP is one of the Southern Ocean most productive regions and where major climate-driven changes are being observed. Hence, these findings are critical to improving our understanding of the natural variability of this unique Southern Ocean ecosystem and how it is responding to present-day climate forcing.

Using a high-resolution model to understand changes in distribution of crabeater seals linked to climate change in the Southern Ocean

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The Southern Ocean is among the fastest changing regions on the planet as a result of anthropogenic climate change. Changes to the physical environment affect the distribution and abundance of marine organisms via direct effects linked to their physiology, and indirectly through disruption of inter-species interactions. We examined the effects of climate change on a highly abundant, ice-obligate species of seal with a circumpolar distribution: the crabeater seals (Lobodon carcinophaga). The crabeaters have a highly specialised diet, with over 90% of their diet made up of Antarctic krill (Euphasia superba, an ice-dependent species). This extreme diet specialisation together with their reliance on sea ice for resting and foraging areas could put the crabeaters at risk of population declines with sea ice cover changes in the Southern Ocean. We used publicly available survey data for crabeater seals collected between the 1970s and 2020s in the Atlantic and Indian sectors of the Southern Ocean. Given the limited observations for ecologically relevant environmental variables, we combined the seal observations with the outputs of a high-resolution ocean-sea ice coupled model (ACCESS-OM2-01). This model was chosen because it can reproduce the observed seasonal cycle and broad baseline climatological conditions of the mixed layer depth and sea ice variables for the Southern Ocean over the past 50 years. We identified key environmental variables that influenced habitat preference in crabeaters, and examined decadal changes in their distribution and abundance at a regional scale (Atlantic vs Indian sectors) since the 1970s. Our results should improve our understanding of the regional impacts of climate change on crabeater seals and shed some light on the distribution of Antarctic krill because of the seals' extreme dependence as a food source.

Observed Intrusion of Warm Modified Circumpolar Deep Water and Its Impact on Dense Shelf Water Formation

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Warm modified Circumpolar Deep Water (mCDW) from the Southern Ocean is able to intrude onto the continental shelf in many regions around Antarctica. These intrusions transport great amounts of heat to the continental shelves, affecting basal melting of ice shelves and sea ice formation in coastal polynyas. In Prydz Bay, the largest embayment in East Antarctica, the strongest intrusion of mCDW over the inner continental shelf in March-July is significantly associated with the variability of westerly winds north of the shelf break in January-May. This is the period when the westerly winds over the Southern Ocean move southward, driving the mCDW to become shallower near the shelf break and allowing more warm water to access the inner shelf. Deep convection in winter can entrains sensible heat of this intruded mCDW at mid-dephts into the surface layer, reducing 45% of the potential sea ice production in the coastal polynya. Our findings provide insight into how seasonal variability of atmospheric forcing in the open ocean will affect warm water inflow and heat transport onto continental shelves, and indicate potential impacts on the Antarctic Bottom Water formation.

Taking the pulse on the Southern Ocean: an internationally coordinated, circumpolar, and year-round mission

The Polar POD expedition: a multi-year research voyage around the Southern Ocean

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The Polar POD is a new, crew-operated, state-of-the-art oceanographic platform designed to enable on-site studies all year-round in the Southern Ocean. It is a 100-m tall drifting structure inspired by the US-Navy FLIP R/V with adaptation to Southern Ocean conditions. When flooded at stern, it flips to vertical to become a stable spar buoy. The design is adjusted to make the POD largely insensitive to waves and able to withstand the conditions of the Southern Ocean down to 55°S. Its vertical stability will minimise air and water turbulence and perturbations of the water-air interface, allowing scientists to perform myriad science measurements in excellent conditions. This oceanographic station will accommodate 3 crew and 4 scientists, in secure and comfortable conditions, with rotations of the crew and science party every two months.

A shipyard has been selected after a bid process and are conducting final engineering studies. They will start construction in Q3 of 2023, which is overseen by IFREMER, the French National Institute for Ocean Science. The Polar POD will be ready to start circumnavigating the Southern Ocean from 2025, for an expected 2-year voyage.

The concept and overall expedition were proposed by Dr Jean-Louis Etienne, a French explorer who has devoted his life to exploration of some of the Earth most harsh environments (Arctic and Antarctic in particular). He has brough together a large group of private sponsors to support the expedition, in addition to what the French Government brought to build the platform and to support the science team that has been formed around the expedition. This includes the French National Centre for Scientific Research (CNRS) and its National Institute for Sciences of the Universe (INSU), the French National Agency for Research (ANR) and the French Space Agency (CNES).

A comprehensive science programme has been designed by a group of about 50 investigators, taking advantage of the Polar POD capability. It includes 4 main research packages. 1- Energy and gas exchange at the air-sea interface and dynamics of the Southern Ocean, 2 – Calibration/validation of satellite observations, 3 – biodiversity and structure of marine ecosystems, from phytoplankton to zooplankton, 4 – human impacts. A transverse activity will specifically consider what underwater acoustics can bring to the overall science programme.

Some of the key science topics that will be addressed are: air-sea exchange of energy and gases, with emphasis on CO2 and the Southern Ocean role on climate, wave dynamics and weather, eddies and turbulence, plankton ecosystems dynamics, impact of acidification, acoustic inventory of marine fauna (marine mammals, krill etc.) and ocean floor noise, validation of satellite measurements (ocean colour, waves, wind speed, temperature), aerosol amounts and sources, aerial observation of marine life like whales and seabirds.

The presentation will review the project rationale, the progress of the preparation phases, and will also suggest avenues for developing international collaboration around the expedition.

Bridging the gap for ice-ocean-ecosystem processes: Case Studies Integrated Observatory for the far East Antarctica-Ross Sea Region RSfEAR

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Our understanding of cross-disciplinary connections for the Antarctic Earth system remains incomplete, especially around its coastal margins. The focus here is on sea ice and oceanic drivers in the Ross Sea-far East Antarctic Region (RSfEAR) - one which spans a large longitudinal range and connects a range of ice shelves and polynyas with sea ice growth and fate and underpins a diverse and rich ecosystem. Here we present recent case studies on how this informs the design for a much needed integrated observing system. We pay attention to regional, gap analysis, future observing system design and wider implications for stakeholders.

The Norwegian Troll Observing Network marine observatories

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The Troll Observing Network (TONe) is a comprehensive research infrastructure network located around the Norwegian permanent research base in central Dronning Maud Land in East Antarctica. As part of eight distinct observatories, the Fimbulisen Ice-shelf Observatory (FIO) consists of autonomous instruments to monitor oceanographic conditions under the ice shelf, together with instrumentation on top of the ice shelf to monitor its surface and basal mass balance. 12 years of ocean temperature and velocity observations showed that a sudden shift toward sustained warm inflow since mid-2016 was caused by large-scale changes in Southern Ocean climate. These changes had direct implications for basal melting at Fimbulisen during 2016-2019, illustrating how remote processes impact the ice shelf mass balance in this sector of Antarctica. These efforts are complemented Multidisciplinary Ocean Moored Observatory (MOMO) that consists of three oceanographic moorings that are located at the Antarctic continental margin north of the Fimbulisen ice front. Those instruments monitor oceanographic, biogeochemical and biological parameters along in the Antarctic Slope Front and seasonal sea ice zone. The moorings are serviced as part of the TrollTransect cruises, together with water samples and profiling data and sea ice stations that are routinely collected from the Troll station supply vessel that visits coast on an annual basis. TONe also includes a drone service that is capable of collecting data over large parts of Dronning Maud Land coastal regions. Several national and international research projects are currently associated with these initiatives and TONe is committed to wide and free access to data from the observatories and drone service to the entire national and international research community. In the horizon of a proposed circumantarctic year, an extension with autonomous platforms, such as under-ice gliders, as well as dedicated campaigns, also using the Norwegian ice breaking research vessel Kronprins Haakon is envisioned.

Seasonal sea ice and snow properties as sensitive indicators for a changing Antarctic sea ice cover

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The Southern Ocean has experienced a slow increase in sea ice extent over the past three decades, in contrast to the sharp decline in Arctic sea ice, but has shown a decreasing trend since 2016/2017, particularly in the Weddell Sea. The strong interannual variability and potential onset of change impacts the processes and interactions between the atmosphere, sea ice, and ocean, which are essential drivers for Southern Ocean ecosystems. However, the causes of these changes and their related impacts on the interactions with other components of the climate system are not yet fully understood. The presence of snow on sea ice is crucial in influencing various interactions, particularly in Antarctica, where the ice remains snow-covered throughout the year. This prevents surface melting during the summer, promotes the growth of sea ice through extensive snow-to-ice conversion processes, and determines the energy budget of the sea ice. Additionally, snow further enhances the light conditions under the ice, and the current high snow load creates highly biologically productive infiltration layers on the sea ice surface.

We hypothesize that seasonal variations in snowpack properties on Antarctic sea ice are sensitive indicators of changing atmospheric forcing, as they could trigger snow-albedo feedbacks that accelerate sea ice melting and retreat. This hypothesis is essential since snow has so far contributed to a positive Antarctic sea ice mass balance due to widespread snow-to-ice conversion processes. However, the current climate warming may reverse this trend, leading to increased surface melting with potential feedbacks for the Earth's climate that have yet to be thoroughly investigated.

The changing seasonal sea ice cycle will affect Southern Ocean ecosystems and biogeochemical cycles, with projections of reduced species, such as pelagic algae, copepods, krill, and fish communities, due to rising temperatures and shorter sea ice duration. However, understanding global environmental changes' effects on the sea ice ecosystem is still limited.

To overcome these limitations, we propose a circumpolar year-round expedition in the Southern Ocean to conduct an extensive analysis of snow and sea ice properties, including biological and biogeochemical variables, along typical drift trajectories in different sea ice age regimes and areas with varying atmospheric influences. The Weddell Sea is one of the key regions to focus on, as it contains the largest perennial sea ice expanse in the Antarctic basin and has recently undergone significant changes.

Closing the Southern Ocean heat and carbon budgets and understanding the underlying processes

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Due to its connection to the ocean interior and the transformation of upwelling deep waters to new surface, intermediate and mode waters, the Southern Ocean plays a fundamental role in the exchange of heat and carbon between the ocean and the atmosphere. These processes dominate the global ocean uptake of excess anthropogenic heat and carbon by the ocean and have thereby substantially slowed global warming over past decades. However, it remains uncertain, how long and to what extent the Southern Ocean will continue to provide such a service, which induces large uncertainties in possible future scenarios globally. Locally, changes in the ocean heat budget strongly affect the sea ice cover and retreating Antarctic glaciers, as well as the ecosystem. To date, there is no consensus on the overall budgets of heat and carbon in the Southern Ocean, and in some regions there are even debates on the sign of the surface fluxes under present-day conditions. Establishing a new baseline that can be used to assess changes in future carbon and heat uptake and release should therefore be a priority. In order to reach this goal, year-round circumpolar observations are required, especially around the data-sparse marginal sea ice zone of the Southern Ocean during winter. Such observations will shed light into the release of heat and carbon from the upwelling deep water and the subduction with newly formed waters. We propose to establish a Southern Ocean wide network of strategically placed biogeochemical moorings to complement year-round shipboard transects, and measurements with biogeochemical Argo floats and gliders to obtain a full snapshot of the heat and carbon budgets for a dedicated year in the period 2027 to 2030, to identify underlying processes and their sensitivity to climate change.

Observing water mass exchange across the Antarctic continental slope

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The large ice shelves fringing the Antarctic continent provide an important buttressing effect to slow down the stream of ice from the Antarctic ice sheet into the ocean. However, ice shelves are losing mass at an accelerated rate in several regions, which may bear consequences for the global sea level. The mass loss is generally attributed to a greater influence of warming ocean waters, which are known to enter the continental shelves from the deep basins across the continental slopes. The exchange may occur as episodic responses to storms or anomalous winds, or occur due to seasonal variations in the strength and position of the pycnocline/thermocline, which are sensitive to stratification and the presence of sea ice and meltwater as well as to advected anomalies from upstream regions. Besides enhancing ice shelf melt when interacting with the ice shelves, the deep waters are also saline and provide salt for dense shelf waters and contribute to the productive Antarctic ecosystems due to their high nutrient content. In return to the warm on-shelf flow, sea ice formation on the continental shelves and ice shelf-ocean-interaction underneath the ice shelves produce the cold and dense waters that in certain regions such as the Weddell and Ross Seas are exported down the continental slopes into the abyss. These dense water are the precursors of the Antarctic Bottom Water (AABW), the lowest limb of the overturning circulation and therefore directly contribute to the global ocean circulation.

Overall, these exchange processes are crucial for the heat budget on the continental shelves and basal melt rates around the Antarctic continent, yet they are difficult to observe due to their sometimes episodic or seasonal nature, further complicated by larger-scale impacts such as meltwater advection. A complete understanding thus requires a concerted circumpolar effort applying a mix of shipboard surveys complemented by long-term ocean observatories.

Circumpolar Antarctic Ice Sheet-Ocean observations: towards an integrated view and improved climate models – Part 2

Understanding the Southern Ocean through model-data synthesis

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Along the West Antarctic coast, modified Circumpolar Deep Water (mCDW) intrudes into West Antarctic ice shelf cavities, causing high ice shelf melting. On the other side, recent studies are pointing out that the East Antarctic ice shelves may be beginning to shrink. Our goal is to understand the past, present, and future state of the Southern Ocean and identify triggers of ocean warming and Antarctic ice loss on various time scales.

We take two approaches to tackle this question. First, to study the circum-Antarctic scale ocean, we evaluate existing ocean reanalysis. We choose Massachusetts Institute of Technology general circulation model (MITgcm) based ocean reanalysis products (ECCOv4r5, ECCO LLC270, SOSE, and GECCO3) and investigate large-scale ocean processes modulating cross-shelf exchange and thus possibly impacting ice shelf melting. Second, we develop regional ocean simulations by downscaling these ocean reanalysis simulations. This way, we achieve much closer agreement with observations by simulating on-shelf hydrography and circulation in fine grid spacing. We further apply optimization techniques (Green's functions and adjoint methods) to improve the model-data agreement. Our recent work, for example, employs the adjoint-model estimation method for the first time with explicit representation of sub-ice shelf cavities to develop an ocean state estimate for the Amundsen and Bellingshausen Seas.

In this presentation, we report our recent progress on the MITgcm-based ocean reanalysis evaluation (ECCOv4r5, ECCO LLC270, SOSE, and GECCO3) in the Southern Ocean. We show our new ECCO LLC270 analysis on the Antarctic Slope Current (ASC) and discuss the interannual variability of the ASC. Next, we summarize our ongoing development of the Antarctic regional simulations (e.g., Amundsen, Bellingshausen, Weddell, and Ross Seas and along the East Antarctic coast) that achieve a good match with observations. We give an overview of key findings and provide examples on how to access model outputs available online and plot fundamental variables. We further introduce our recent model development towards ice-ocean-biogeochemistry coupled and paleo-ocean simulations.

Ocean ridges impact the strength and location of deep warming and sea level changes

Dr Kathryn Gunn[1,2], Professor Matthew England[3], Dr Steve Rintoul[1]

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Antarctic Bottom Water (AABW) fills over 30% of the abyssal ocean and it is warming, contracting, and slowing down. These changes are expected to impact the properties of the abyssal ocean and thus sea level. However, these patterns of change are complex and have only been examined in a bulk sense, ignoring the potential role of topographic barriers in the ocean (i.e., ridges). Here, we show that ocean ridges act as barriers to AABW advection: exacerbating warming around their slopes and creating uneven warming northward of Antarctica. These findings suggest that contraction of AABW, driven by its slowdown, can explain deep warming in Antarctic-adjacent Ocean basins, and creates hotspots of warming around ridges and along its northward path. The impact of deep warming on sea level is investigated and presented. These changes are linked with freshening of Antarctic coastal waters.

Drivers of change in Antarctic Bottom Water and the deep overturning circulation

Dr Steve Rintoul[1,2], Dr Kathy Gunn[1], Dr Alessandro Silvano[3]

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Antarctic Bottom Water (AABW) has warmed, freshened, and reduced in volume in recent decades. Changes are largest near Antarctica but have spread through much of the abyssal ocean. The magnitude of the changes is sufficient to make a substantial contribution to sea level rise, global energy budgets, and global biogeochemical cycles. Furthermore, because the properties of AABW are set by complex interactions between the ocean, atmosphere and cryosphere, observations of AABW also provide an indicator of variability and change in high latitude climate.

While the evidence for change in AABW properties has grown in recent decades, the physical mechanisms driving the observed changes are poorly understood. Recent observations, model simulations, and natural experiments have provided insights into the sensitivity of AABW to changes in forcing. In particular, recent work has highlighted the critical role of the freshwater balance on the Antarctic continental shelf. Freshening of shelf waters reduces both the density and export of Dense Shelf Water from the continental shelf, which, in turn, reduces the density, volume, and transport of AABW. As the densest layers thin, isopycnals descend, causing warming throughout much of the water column and a poleward shift of relatively warm Circumpolar Deep Water (CDW). Ventilation of the abyss is reduced both by a slowdown of the overturning circulation and by replacement of well-ventilated AABW by poorly-ventilated CDW. Warming and contraction of AABW ultimately reflects freshening on the continental shelf.

The dependence of AABW properties on shelf water salinity means that AABW is sensitive to the variety of processes that contribute to the freshwater balance, including glacial melt, sea ice formation and melt, along- and cross-shelf exchange, precipitation, and subglacial discharge. Each of these terms is poorly constrained by observations, and a quantitative understanding of the time-varying freshwater balance of the Antarctic continental shelf remains out of reach. Qualitatively, input of freshwater by glacial melt likely explains the long-term freshening trend, particularly in the Ross Sea and other regions downstream of the Amundsen Sea where rapid melt is underway. But increased sea ice formation can be sufficient to temporarily reverse the trend and may a larger relative role in the Weddell Sea and other regions remote from the large meltwater source in the Amundsen Sea. Feedbacks may play an important role. In particular, freshening-driven contraction of AABW allows warm CDW to approach the continental shelf, with potential to drive ice shelf melt and further freshening; freshening also increases stratification on the shelf, allowing warm water at depth to access ice shelf cavities. As the rate of glacial melt and freshwater input is expected to increase in a warming climate, we can anticipate that AABW will continue to warm, freshen, and contract; the deep overturning circulation will slow; and abyssal ventilation will decline.

Abyssal ocean overturning slowdown and warming driven by Antarctic meltwater

Professor Matthew England[1], Dr Qian Li[2], Professor Andy Hogg[3], Dr Steve Rintoul[4], Dr Adele Morrison[3]

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The abyssal ocean circulation is a key component of the global meridional overturning circulation, cycling heat, carbon, oxygen and nutrients throughout the world ocean. The strongest historical trend observed in the abyssal ocean is warming at high southern latitudes, yet it is unclear what processes have driven this warming, and whether it is linked to a slowdown in the ocean's overturning circulation. Furthermore, future change in the abyssal overturning remains uncertain, with the latest CMIP6 projections not accounting for dynamic ice-sheet melt. In this talk I will present new transient forced high-resolution coupled ocean – sea-ice model simulations to show that under a high emissions scenario, abyssal warming is set to accelerate over the next 30 years. We find that meltwater input around Antarctica drives a contraction of Antarctic Bottom Water (AABW), opening a pathway that allows warm Circumpolar Deep Water greater access to the continental shelf. The reduction in AABW formation results in warming and aging of the abyssal ocean, consistent with recent measurements. In contrast, projected wind and thermal forcing has little impact on the properties, age, and volume of AABW. These results highlight the critical importance of Antarctic meltwater in setting the abyssal ocean overturning, with implications for global ocean biogeochemistry and climate that could last for centuries. I will conclude this talk by outlining the most pressing aspects of coupled climate - cryosphere model development that need advancing over the coming years.

POSTER ABSTRACTS

POSTER SESSION BY THEME

Air-sea interactions and climate variability in the Southern Ocean

POSTER #1

Representation of mesocyclones in P-SKRIPS, the air-ocean-sea ice numerical model for the Ross Sea

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Mesocyclones, or Polar Lows, are under-studied features in the Ross Sea Regions (RSR), yet they can locally impact precipitation, flying conditions and the state of sea ice. Over the RSR, mesocyclones typically form from the conjunction of a cold continental flow off the coast of Adelie Land meeting a northern, warmer flow. It is also thought that the intensity and longevity of such mesocyclones is highly dependent on the surface conditions (and therefore sea ice cover), highlighting the impact of ocean, sea ice and atmosphere interactions in the sustenance of the mesocyclones.

We present here P-SKRIPS, a new, coupled model setup that is physically consistent in the representation of ocean/atmosphere/sea ice interactions for polar climates (Malyarenko et al, 2022). Our coupled model is the first that includes a full conservation of heat and mass fluxes transferred between the climate (PWRF) and sea ice-ocean (MITgcm) models. It also allows us to examine in detail open water, sea ice cover, and ice sheet interfaces and the processes that span between models in the RSR.

We have identified a mesocyclone event on the 6th to 8th of January 2014, visible in several regional climate models and reanalyses. The mesocyclone starts spinning off the coast of Victoria Land and moves eastwards over the open ocean, and loses intensity and disappears after two days, once it gets to the sea ice edge. We have run a series of sensitivity studies affecting the orography, the sea ice cover and the ocean-atmosphere interactions. The results indicate that the development and path of the mesocyclones, as well as the distribution of precipitation locally, depend on surface conditions and the sea ice cover.

POSTER #2

Impacts of Sea Ice on Ocean Gravity Waves Simulations in the Antarctic Peninsula Region

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Ocean gravity waves play an important role being the primary source of energy for ice breakup in the marginal ice zone (MIZ) and the main driver determining its properties and sea ice extent. On the other hand, wave energy is dissipated and scattered by the sea ice. To analyze the effects of sea ice on waves, the WAVEWATCH III model was used to simulate wave-ice parameterizations focused on Antarctic Peninsula and surrounding area. Both conservative and non-conservative parameterizations were activated, and comparisons were made considering observations, particularly significant wave height (SWH) data from an anchored buoy near to King George Island, as part of ATMOS project supported by Brazilian Antarctic Program. Additionally, the simulations were analyzed using the gridded merged satellite SWH data from Copernicus Marine Environment Monitoring Service. The results indicate a greater reduction in wave energy on simulations that consider only non-conservative process, particularly towards MIZ, and not significative changes activating only conservative process. The combination of non-conservative and conservative parametrization in the same simulation resulted in a better performance, especially if the turbulent laminar regime is activated. It showed a smaller spatial BIAS and RMSE (considering satellite) and a slightly better statistical performance considering the buoy time series, mainly for wave direction distribution. A SWH overestimation was noticed in the Weddell Sea, considering the satellite data, and may be related to the scattering parametrization. The transfer of energy by dissipation and the spreading by scattering occurred around Antarctica Peninsula and surroundings, indicates that wave-ice parametrization could improve wave simulations towards MIZ, however, further investigation is needed to better comprehend the wave-ice parametrization effects. Nevertheless, the results obtained suggest wave simulation enhancement within Antarctic Peninsula and the area of study.

POSTER #3

Seasonal Sea-ice Albedo Variations in Antarctica and its linkage with ocean-atmospheric parameters

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Surface albedo (SAL) is a necessary parameter for climate studies as it affects the radiation budget of the atmosphere-earth system and influences the global climate. An analysis of long-term temporal and spatial variability of spring-summer SAL over the five longitudinal sectors around Antarctica: the Weddell Sea (WS), the Indian Ocean (IO), the Western Pacific Ocean (WPO), the Ross Sea (RS), and the Amundsen-Bellingshausen Sea (ABS) is done and investigated the interrelationships between SAL and climatic variables such as sea ice concentrations (SIC), sea surface temperature (SST), 2m air temperature (T2m), Turbulent Heat Flux (THF), total cloud cover (TCC), etc. This study aims to analyze the change in SAL in two different timescales: pre-2015 (1979–2015) and post-2015 (2015–2021) to understand the variation of sea ice and recognize the trend of climate change in Antarctica. Time series, correlation, and composite analysis were performed through linear regression using SAL and climatic variables. Sector-wise study shows two different trends, a positive trend (pre-2015) and a decreasing (2016–2021) trend all over Antarctica, except in the ABS during summer, which shows the opposite trend. The results of this research indicate a higher SAL in the west Antarctica (WA) sea ice region in comparison to east Antarctica (EA). The SAL was significantly positively (or negatively) correlated with the SIC (SST, T2m, and THF), and these scenarios were held for all five longitudinal sectors. The increasing (decreasing) SAL means that the Antarctic Sea ice region reflects (absorbs) more solar radiation and absorbs less, leading to a decrease (increase) in temperature and much sea ice snowfall (sea ice melting), further resulting in an increase (decrease) in SAL. In this study, seasonal time scales, regional-scale processes and atmospheric-oceanic forcings play a significant role in the seasonal variation of SAL and opposing regional trends.

Keywords: Antarctic regional sectors, seasonal variations, surface albedo, sea ice concentration, atmospheric-oceanic forcings, trend, composite analysis

Circumpolar Antarctic Ice Sheet-Ocean observations: Towards an integrated view and improved climate models

POSTER #4

Outcomes of Research of Ocean-ice BOundary InTeraction and Change around Antarctica (ROBOTICA)

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Under the project named as Research of Ocean-ice BOundary InTeraction and Change around Antarctica (ROBOTICA) during 2016-2022, the Japanese Antarctic Research Expedition scheme tried to utilize state-of-the-art unmanned observations such as under-ice oceanographic, seafloor and cryospheric observations using ROV/ AUVs, geodetic network observations of ice/ocean motion and deformation using GPS/ GNSS, and oceanographic observations using tethered and moored profiling observation systems to acquire the detailed environmental information both in time and space. With these implementations, we made intensive, interdisciplinary observations for the three typical regions of importance in East Antarctica.

In Lützow-holm Bay off Soya Coast, warm water heat intrusion and resultant ice-ocean interaction has been clarified. In front of Shirase Glacier, our shipboard hydrography has detected the warm water inflow through the deep glacial canyon and subsequent meltwater outflow in the upper layer. Direct measurements through the ice shelf of the Langhovde Glacier provided the evidence of the under-ice ocean circulation melting the ice from the below. Weddell seals captured the access of deep near-surface warm water even in autumn. For the ice system, satellite measurements clarified the interannual changes in motion of landfast sea ice and Shirase Glacier Tongue, indicating the mutual interactions and in-situ measurements revealed the interannual variability in sea ice properties.

For the region off Cape Darnley Polynya, Mac. Robertson Land Coast, significant progress has been made for the understanding in the sea ice and dense water formation processes. The minimum of sea ice cover in 2017 has provided the excessive heat in melting the Amery Ice Shelf to anomalously freshen the Cape Darnley Polynya. These changes in summer environment can change the relatively stable sea ice production in winter so far for the coming decades. The findings were made possible with the technical deployment of a state-of-the-art tethered profilers.

Off Sabrina Coast, we conducted intensive oceanographic and geophysical observations. Bathymetric survey with multi-narrow beam were effective and describes new and detailed topographic features. Hydrographic measurements, including CTD/MS and XCTD, revealed the ubiquitous presence of deep warm water in this region. Air-borne oceanography helped enhance the spatial sampling in difficult access area, and largely expand the distribution of water mass property. Warm water was found near the bottom throughout the study area, with its temporal change from days to years scales and shapes the nutrient and other chemical water compositions.

Analysis of various samples obtained by ROBOTICA is still on-going for the chemical, biological, and ecological studies. New species have been identified from the sediment samples. Sediments and their cores were taken for the first time in this region were conducted at the marginal ice zone off Dalton Polynya, which will shed new light on the quaternary environmental change. Chemical composition of sea water will provide insight on the carbon cycle in the Southern Ocean. Our interdisciplinary achievements will further promote an acceleration in understanding of the sector and realization of sustained observation system around Antarctica.

POSTER #5

Keeping an eye on the ocean/ice-shelf system in the southern Weddell Sea

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The southern Weddell Sea features a vast continental shelf with mainly near-freezing waters that help to presently maintain moderate melt rates underneath the Filchner-Ronne Ice Shelf, the largest ice shelf on earth by volume. The region provides a globally significant part of the dense waters that are exported into the abyss as precursors of Antarctic Bottom Water, and is thus a relevant part of the global ocean circulation. In exchange of the dense outflow, the region receives a seasonal inflow of warm deep water, which can propagate all the way to the ice shelf front. While the oceanic on-shelf heat flux is presently limited in space and time, projections indicate that in coming decades a large-scale influx of warm water into the cavity may change the regional circulation and lead to drastically increased basal melt rates.

A concerted international effort maintains long-term observations underneath the Filchner Ice Shelf and on the continental shelf and slope near Filchner Trough, in order to monitor the relevant inflow of warm deep water and the outflow of dense water into the deep ocean. Additional moorings are placed upstream at the continental slope in the eastern Weddell Sea, to identify for instance anomalies in meltwater advection, which could alter the ocean's structure and impact the inflow of warm water. Here we present plans for extending, integrating, and operating the existing long-term observatories to increase our knowledge of the natural variability of the ocean-ice shelf system, and to allow early identification of possible changes of regional or global importance.

POSTER #6

Topography-mediated Transport of Warm Deep Water across the Continental Shelf Slope, East Antarctica

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Warm Deep Water intrusion over the Antarctic continental shelves threatens the Antarctic ice-sheet stability by enhancing the basal melting of ice shelves. In East Antarctica, the Antarctic Slope Current (ASC), along with the Antarctic Slope Front (ASF), acts as a potential vorticity barrier to prevent the warm modified Circumpolar Deep Water (mCDW) from ventilating the cold and fresh shelf. However, mCDW onshore transport is still observed within certain shelf regions, such as submarine troughs running perpendicular to the continental shelf. This study focuses on the dynamic mechanisms governing mCDW intrusion within a submarine trough over the fresh shelf regions, East Antarctica. Based on an idealized eddy-resolving coupled ocean-ice shelf model, two high resolution process-oriented numerical experiments are conducted to reveal the mechanisms responsible for the mCDW onshore transport. Three dynamic mechanisms governing cross-slope mCDW intrusion are identified: 1) the bottom pressure torque, 2) the topography beta spiral, and 3) the topography Rossby waves. These three mechanisms simultaneously govern the mCDW intrusion together. The bottom pressure torque plays a leading role in driving the time-mean onshore flow whose vertical structure is determined by the topography beta spiral, while the topography Rossby waves contribute to the high-frequency oscillations in the onshore volume and heat transport. The simulated spatial distribution and seasonality of mCDW intrusion qualitatively coincide with the observed mCDW intrusion over fresh shelf regions, East Antarctica. Both the topography beta spiral and the ASC play an important role in governing the seasonality of mCDW intrusion.

POSTER #7

OCEAN:ICE, towards a circumpolar view of ice-ocean interactions and their climatic impact

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OCEAN:ICE (Ocean-Cryosphere Exchanges in ANtarctica: Impacts on Climate and the Earth System) is a new four year (start November 22) Horizon Europe project, funded by the European Commission and UKRI. It will push forward the boundaries in our understanding of how the Antarctic ice sheet and surrounding Southern Ocean influences our global climate, as well as reduce the dangerous levels of uncertainty in freshwater flux and associated sea level rise from future melt. Many past and present projects focus on single elements of this question; ocean circulation, ice sheet change and tipping points. OCEAN:ICE will bring these aspects together and consider the important role of feedbacks between them and the global climate. It will combine both circumpolar observational and modelling approaches to improve our understanding of fundamental ice-ocean interactions and our ability to model them, as well as rigorous approaches to quantifying our present uncertainty in predictions of future change.

Bringing together 17 centres from across the EU and UK, as was well as numerous partner nations and organisations, including many SOOS member, it will make numerous new observations around the Southern Ocean and under Antarctic ice shelves. These will include AUV observations under 'warm' ice shelves in west Antarctica and through ice shelf deployments under the 'cold' Fimbul ice shelf, deployments of quasi-stationary floats over continental shelves and under seasonal sea ice, and numerous mooring deployments, including in previously unexplored bottom water export pathways.

These observations, along with historical datasets, will be examined to explore not only the controls on export/import of the continental shelves to/from the open ocean, but also the circumpolar connections between regions of significant ocean-ice sheet interaction. Ultimately these observations will support modelling efforts to constrain past and future ice sheet melt and to understand the impacts and feedbacks such melt will have on the global climate system over the coming centuries.

This talk will discuss the scientific objectives of OCEAN:ICE and planned fieldwork. It will emphasise the importance of a circumpolar approach to assessing the climate scale impact of the changing Southern Ocean and Antarctic ice sheet, and how the SOOS network may help support such observations and be of particular benefit to developing coupled ice sheet-climate models.

How Argo is transforming our understanding of the Southern Ocean in the global climate

POSTER #8

Southern Ocean seasonal sea ice bloom net community production and relationship to sea ice retreat

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The Southern Ocean Seasonal Sea Ice Zone (SIZ) spring is characterized by sea ice retreat and the development of phytoplankton blooms. While the existence of blooms associated with retreating sea ice is well documented, the importance of under-ice production and the bloom's impact on carbon and nutrient cycling is unclear. We utilize circumpolar biogeochemical profiling float observations to assess SIZ blooms and associated bloom net community production (bNCP). We examine 64 individual float seasons and relate the timing of sea ice retreat to phytoplankton growth, the drawdown of surface nitrate, and estimated bNCP. The onset of biological production follows initial sea ice breakup and the majority of bNCP occurs under partial sea ice cover. Estimates of bNCP range from <1 to >4 mol C m^{-2} $bloom^{-1}$, with higher bNCP when sea ice breakup occurs early in the year, and the highest bNCP observed by floats where micronutrients may be supplied from continental sources or topographically-enhanced mixing. We hypothesize that differences in the timing of sea ice breakup and retreat may alter ecosystem dynamics that control bNCP, and that micronutrient limitation and grazing may lead to decreased NCP rates after total sea ice retreat. These results indicate that satellite-derived export estimates will underestimate bNCP in the SIZ and have implications for net community production in the currently changing Southern Ocean sea ice regime.

POSTER #9

Monthly climatology of Southern Ocean below sea ice

Dr Kaihe Yamazaki[1,2], Dr Helen Phillips[1,2,4], Dr Maxim Nikurashin[1,2,4], Dr Paul Spence[1,2,4], Dr Laura Herraiz-Borreguero[3], Dr Matthis Auger[1,2], Dr Nathan Bindoff[1,2,4]

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The substantial variation in sea ice extent dictates the seasonality of the Southern Ocean. Despite recent advances in monitoring the Southern Ocean, sea ice still prevents us from observing the subsurface ocean and its seasonal variability. Over the past two decades, the global array of Argo floats with ice capability and biologging techniques with marine mammals have provided insightful observations of the under-ice ocean. These observations now cover the circum-Antarctic domain throughout the year, allowing us to construct a three-dimensional monthly climatology of the Southern Ocean thermohaline properties. To achieve this, in-situ temperature and salinity were gridded onto 1° latitude x 2° longitude bins on pressure coordinates with 10 dbar intervals. The constructed climatology uncovers various seasonal cycles under ice, such as (1) the spatial variation in the seasonal mixed layer formation, (2) surface salinity increase due to sea ice formation, (3) northward advection and subduction of freshwater sourced from sea ice melt, and (4) asymmetric water displacements in deep layers (200–800 m), likely reflecting a deep ocean response to surface buoyancy forcing. The gridded data are tagged with standard deviation and the number of original data, capable of formal statistical analysis. The dataset is the first monthly climatology of the Southern Ocean interior and will serve as a tool for understanding the mechanisms of its seasonal variation as well as for validating numerical models.

Merged Session 2 = New insights and cross-disciplinary observing requirements for (circum-) Antarctic sea-ice processes

POSTER #10

Use of a drifter array for observing temporal variability of pelagic ecosystem and material cycling in the seasonal ice zone

Dr. Ryosuke Makabe[1,2,3], Dr Keigo Takahashi[2], Ms Chiho Tsuchiya[2], Dr Masayoshi Sano[4], Dr Masato Ito[1], Mr Ryo Matsuda[5], Dr Shintaro Takao[6], Dr Norio Kurosawa[5], Dr Masato Moteki[1,3]

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Seasonal Ice Zone (SIZ) is one of the typical features of the Southern Ocean ecosystem. Sea ice, which regulates environmental conditions (e.g. light penetration and iron supply) in SIZ, strongly affects primary production and material cycling through the food web. The relationship between surface environments and biological pumps has usually been investigated using sediment traps attached to a mooring in other areas including the Arctic Ocean, although the mooring array failed to measure the surface environment (<500 m depth) in the Southern Ocean due to presence of icebergs. We conducted a surface drifter observation using a newly developed ice-resistant GPS buoy to understand the relationship between surface environment and the export flux during a sea ice melting season.

The drifter was deployed (December 9, 2019) and retrieved (February 16, 2020) by the icebreaker Shirase under the 61st Japanese Antarctic Expedition. Sinking particles were sampled at depths of 60 m and 150 m by time-series sediment traps. Water temperature, salinity, photosynthetically active radiation (PAR) and chlorophyll fluorescence were measured using sensors placed at each depth (10, 20, 30, and 40 m). In addition, an upward looking acoustic Doppler current profiler (ADCP, 300 kHz) was placed at ca. 70 m depth for velocity field and zooplankton distribution. CTD observations and vertical tows of a closing net were conducted when the buoy was deployed and retrieved, and seawater at each depth were sampled by a bucket and Niskin bottles. Sea ice around the vessel was collected when the buoys were deployed. Similar observation was conducted near the path of the drifter on January 22, 2020 during the Umitaka maru cruise (UM19-08). Samples of seawater, sea ice, and sinking particles were fixed using neutral Lugol-iodine solution. The waters, sea ice, and sinking particles were used for elemental, molecular and microscopic analyses.

Sea ice concentration was almost 100% when the drifter was deployed, then rapidly decreased from December 27 to January 5, finally reaching 0% on January 12. PAR increased with sea ice concentration decreased. During the period, a peak of chlorophyll fluorescence was found at 20 m depth, and then, shifted to deeper depths. The chlorophyll fluorescence peaks were continuously found around pycnocline, which located below the euphotic layer, suggesting that they were caused by the accumulation of phytoplankton at the pycnocline rather than the production. Nanoflagellates (mainly Phaeocystis antarctica) and Fragilariopsis cylindrus were dominant protozoan in sinking particles. The flux of particle organic matter (POC) ranged from 38.1-102.5 and 16.9-156.3 mg C m-2 day-1 at 60 and 150 m depth, respectively. These temporal changes were not consistent with changes in the chl. fluorescence. The ADCP derived vertical distribution of zooplankton was concentrated in shallower waters, of which the peak abundance was found at the depth of the chl. maximum during sea ice melt. Therefore, POC flux was likely to be attenuated by zooplankton community above 60 m depth.

POSTER #11

Diversity and community structure of eukaryotic organisms in East Antarctic sea ice revealed by high through-put DNA sequencing

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In the Southern Ocean, high primary production is supported by ice-edge bloom in the seasonal ice zone (SIZ) from spring to summer. Sea ice melting facilitates growth of ice-edge phytoplankton due to the release of the micro-nutrient iron and ice algae (seeding population), and an improvement of the light environment. The difference in the ice-algal community composition of sea ice is considered one of the important factors in the occurrence of ice-edge phytoplankton bloom. The study on the algal abundance and composition in sea ice is essential for a better understanding of the biochemical cycle in the Southern Ocean. Microscopic observation has been a powerful tool to estimate algal abundance and composition accurately. However, extensive knowledge of various phytoplankton morphological features is needed. In contrast, a high through-put DNA sequencing technic is useful to examine the community structure. In this study, the eukaryotic diversity and community in the sea ice in the Indian Ocean sector of the Southern Ocean were analyzed using high through-put DNA sequencing.

Field observations were conducted in off Totten Glacier, near Dalton Polynya, off Vincennes Bay, off Cape Darnley, and Lützow-Holm Bay from December 2019 to March 2020. Brash ice and new ice (a total of 94 samples from 21 stations) were sampled. A 200 g sea ice from each station was melted in 800 mL of 3% NaCl artificial seawater. The sea-ice meltwater was filtered and extracted DNA using DNeasy PowerWater Sterivex Kit. The V9 region of 18S rRNA gene was amplified using the extracted DNA. The Illumina MiSeq sequencing was performed. The clustering of amplicon sequence variants (ASV), assignment of taxonomic affiliations, and statistical analyses were performed using QIIME2 (ver. 2022.8), the PR2 database (ver. 4. 12. 0), and R (ver. 4.2.2.).

The sequences were clustered into 1346 ASV. The number of specific ASV in each area was 650, 130, 95, 132, and 104 in the off Totten Glacier, near Dalton Polynya, off Vincennes Bay, off Cape Darnley, and Lützow-Holm Bay, respectively. The most relatively abundant Ochrophyta group were Raphid-pennate_X sp. (<25.5%), Stellarima microtrias (<18.6%), and Raphid-pennate unassigned (16.4%). Raphid-pennate sp. and unassigned were identified as the genus Fragilariopsis using the BLAST program. Although the relative abundances were lower than Raphid-pennate group, Chaetoceros (<2%), Actinocyclus (<3%), and Pseudo-nitzschia (<9%) were detected in all regions. Phaeocystis sp. was also detected in all regions, but relative abundance was low (<1%). The most relatively abundant dinoflagellate group in all regions were Dinophyceae unassigned (<25.6%), Polarella glacialis (<4.4%), and Gyrodinium sp. (<1.1%). The sequence of Dinophyceae unassigned was similar to that of cultured strain W-5 (belonged to Dinophyceae) usingthe BLAST program. Raphid-pennate were most abundant in off Totten Glacier, near Dalton Polynya, and Lützow-Holm Bay. In contrast, Dinophyceae unassigned and Stellarima microtrias were most abundant in off Cape Darnley and off Vincennes Bay, respectively. The diatom genus Pseudo-nitzschia was more abundant in Dalton Polynya than in other regions. The difference in community structures in the sea ice of the regions was observed.

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POSTER #12

The role of sea ice in the carbon cycle of polar oceans

Dr Sebastien Moreau[1], Dr Martin Vancoppenolle, Dr Odile Crabeck, Pr Bruno Delille, Dr Kristina Brown, Pr. Karley Campbell, Dr. Melissa Chierici, Pr. Brent Else, Dr. Agneta Fransson, Pr. Francois Fripiat, Dr. Nicolas-Xavier Geilfus, Dr. Elizabeth Jones, Pr. Delphine Lannuzel, Johanna Langer, **Dr Klaus Meiners**[1], Dr. Lisa Miller, Sofia Muller, Pr. Daiki Nomura, Pr. Soren Rysgaard, Dr. Nadja Steiner, Pr. David Thomas, Pr. Jean-Louis Tison

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Polar oceans are disproportionately impacted by climate change. Yet, they play crucial roles in mitigating climate change, as both the modern Arctic and Southern Oceans are known to act as large atmospheric CO2 sinks. However, this understanding is almost entirely based on studies of open water areas and seasons. To understand fully the role of polar oceans in the global carbon cycle, we must constrain the carbon cycle of ice-covered regions and seasons. Over the last two decades, large international efforts have been dedicated to understand the role of sea ice in the carbon cycle. From this work, several sea-ice related physical and biogeochemical processes are now thought to play an important role; they include air-ice CO2 fluxes, the sinking of carbon-rich brines to the oceans' abysses, the precipitation and dissolution of calcium carbonate in sea ice, and the biological production that takes place within sea ice. By using a compilation of most existing data on sea ice Dissolved Inorganic Carbon (DIC) and Total Alkalinity (TA), representing a total of 343 ice cores in the Arctic and Southern Oceans collected between 2003 and 2020 across all seasons, we synthesize here the most recent knowledge of these processes while comparing Arctic and Southern Ocean sea ice biogeochemistry. Finally, the processes that require further studies for a complete understanding of the role of sea ice in the carbon cycle of polar oceans are discussed.

POSTER #13

Seasonal variability of submesoscale dynamics in Southern Ocean marginal ice zones

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Accurately modeling sea ice thickness and extent is needed to improve weather forecasts and future climate projections, yet the predictability of Antarctic sea ice at seasonal to interannual timescales in coupled Earth System Models (ESMs) remains poor. One contributor to sea ice forecast errors is the coarse resolution of ESMs, which do not resolve episodic sea ice heating and advection by mesoscale and submesoscale eddies. Marginal ice zones (MIZs) are particularly susceptible to the development of submesoscale flows due to strong lateral buoyancy gradients associated with sea ice growth and melt. However, the magnitude and nature of submesoscale dynamics can vary significantly within Southern Ocean MIZs. Investigating spatiotemporal variations in submesoscale ice-ocean coupling requires resolving both small and large scales, which is challenging from a modeling and observational perspective. Here, we examine the seasonality of submesoscale turbulence in Southern Ocean MIZs using a 1/48° global simulation and in situ observations from instrumented elephant seals. We show that the seasonal cycle of sea ice greatly modulates the seasonal variability of submesoscale activity. In the open ocean, submesoscale flows are particularly energized in winter by baroclinic instabilities that develop in deep winter mixed layers. Indeed, for a given lateral buoyancy gradient, a deeper mixed layer will store more potential energy. However, in MIZs, lateral buoyancy gradients themselves vary seasonally and Ekman buoyancy fluxes are damped in winter by sea ice cover. Consequently, submesoscale activity peaks later in the year, during the transition from winter to spring.

Understanding this seasonal evolution of submesoscale dynamics is crucial to increase predictability of Antarctic sea ice on short to long timescales and understand biogeochemical variability in MIZs.

POSTER #14

In-situ static sea ice imaging using LiDAR and depth camera technology

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We present a methodology for the in-situ extraction of a reliable 3D representation of sea-ice which can aid in improving the understanding of the sea-ice dynamics in the Antarctic Marginal Ice Zone (MIZ). The physical properties of sea-ice, such as floe size distribution and floe geometry, affect surface wave formation and propagation, mostly through damping ocean kinetic energy and attenuating surface wave amplitudes. Current models utilise simplified geometries to represent pancake ice floes. However, the physical exterior geometry of the pancake floe has an impact on the experienced frictional forces between the ice and waves, which, in turn, affects the motion of ice in the wave-field. Small-scale surface roughness contributes to the skin friction experienced in atmosphere-ice-ocean interactions and the large-scale geometry impacts the form friction experienced.

This work reports on an investigation into the use of terrestrial LiDAR (Livox Avia) and depth camera technology (Intel Realsense D455) to create realistic 3D models of pancake ice floes. Stereo vision provides a dense map of the imaged surface, but the data are susceptible to noise and only suitable for short-range targets. LiDAR has the advantage of increased accuracy of the point cloud, but this map is far sparser than that from the camera data, whilst it can also be used for longer-range targets. Both LiDAR and stereo imaging have their own limitations and, hence, a sensor-fusion approach is employed to overcome the limitations of the individual sensors.

This work explores the insights gathered from a series of scans of pancake ice floes extracted from the Antarctic MIZ whilst on board the SA Agulhas II on the SCALE Winter 2022 expedition. The imaging methodology is based on the historical cruise activity of extracting pancake sea ice floes and depositing them on wooden boards on the vessel's deck for ice coring to occur. A series of static scans are taken from around the extracted floe using the sensor rig attached to a tripod. The sea ice surface lacks structured features in its rough geometry, making it challenging to correctly map the scans taken from different viewpoints. Visual markers on the pancake boards were used instead to assist the initial mapping process. After this, a unique processing pipeline is used which makes use of the Iterative Closest Point (ICP) algorithm. Following this, a merging of the two sensors is performed to create a reliable 3D scan.

Analysis of the pancake scans is performed following work by Landy et al. (2015), resulting in an extracted RMS height which is an indicator of roughness. A preliminary analysis of the LiDAR pancake data collected resulted in a surface roughness of 2.42 cm. A thorough evaluation of this reconstruction method was then performed by scanning objects of known geometry to understand the limitations of the system and methodology. Additionally, the 3D characterization can be used to determine the drag coefficient using CFD software. Preliminary results suggest that this multi-sensor approach using static LiDAR and camera scans can reliably capture the large-scale and small-scale geometries of pancake sea ice.

POSTER #15

Analysis of high frequency inertial time series collected during the passage of a polar cyclone in the Antarctic MIZ

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Waves-in-ice are a geophysical phenomenon that continues to be a key feature of models aiming to predict sea-ice area in the Antarctic. To this end, a new generation of cost-effective ice-tethered waves-in-ice instruments (UCT SHARC Buoys) were developed and deployed to the Antarctic MIZ in the Southeast Atlantic sector during the winter season (July 2022). The instruments were equipped with an ICM20649 6DOF inertial measurement unit and sampled at 104 Hz. Six instruments were deployed onto consolidated ice in the Marginal Ice Zone. The deployment coincided with a polar cyclone which resulted in the breakup and melt of the consolidated ice on which the devices were deployed.

Four devices were retrieved, two with complete high frequency inertial datasets. These datasets represented periods of 2.5 and 4 days respectively. To the authors' knowledge these are the first such datasets collected. This is due to the fact that waves-in-ice instruments generally send summary wave statistics as the transmission of the raw data is exceptionally expensive with the current satellite networks in the region (predominantly the Iridium network) and the challenge in locating and retrieving the instruments.

The high frequency data is important for two key reasons. Firstly, it allows the interrogation and analysis of the raw data used to generate the summary wave statistics transmitted by instruments of this type. Different approaches to sensor fusion of the

IMU data to calculate the vertical acceleration of the device are shown. This is necessary as waves-in-ice devices are generally ice-tethered meaning that they are deployed onto ice floes and so use the movement of the floe as a result of wave excitation as a proxy measurement for the underlying wave activity. Therefore, contamination of the wave data by the dynamics of the floe needs to be quantified. This leads on to the second reason, the ancillary waves-in-ice phenomena. Most notably, the presence of floe-floe collisions in the inertial time series. Spikes in the collected time series which coincide regularly with the mean measured wave period are strong and easily identifiable within the dataset. These are thought to be floe-floe collisions due to this regularity being similar to wave tank testing results.

The floe-floe collisions and their regularity are of interest as they can provide insights into several waves-in-ice processes such as wave attenuation, floe rafting, and especially the abrupt winter breakup of consolidated ice in observed during this experiment.

The results show the rapid onset of the storm both in significant wave height (showing a substantial increase from ~1 to ~3 m) and mean wave period (substantial decrease from ~ 15 – 17 s to ~10 – 11 s). Additionally, the high frequency inertial time series indicate that collisions occur often enough and are of significant duration to potentially bias the measurements from the device if not properly filtered from the time series. Secondly, the collisions increase substantially in frequency during the onset of the storm, likely coinciding with the breakup of the consolidated ice.

POSTER #16

Enhanced winter biogeochemical activity in growing Antarctic sea ice

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The study of Antarctic first-year sea-ice biogeochemistry has been limited by samples mostly being collected in pack ice during summer, with few winter data available. Measurements from the Antarctic marginal ice zone (AMIZ) have proven even more difficult to obtain. The AMIZ is a broad, circumpolar feature of the Southern Ocean found at different latitudes during the year where light and nutrients are high enough to sustain primary production and influence ecosystem functioning. We present the first biogeochemical dataset from growing ice collected in the Atlantic AMIZ during winter 2019, including measurements from young pancake ice (YI) and consolidated first-year ice (FYI). Temperature, salinity, crystal structure, δ18O, chlorophyll and nutrient concentrations were used to investigate the winter sea-ice habitat and decipher the conditions under which the ice formed and grew. Model simulations support the hypothesis that nutrient accumulation in advancing sea ice is not explained by passive seawater entrainment alone. Rather, our data suggest that winter sea ice is biologically active and acts as a reservoir of concentrated nutrients during the ice-growth season. The transition from YI to FYI does not appear to be a linear progression of thickness with habitat space reduction as sea ice consolidates. Instead, FYI results from multiple cycles of breaking and rafting of YI, which conserves the biogeochemical properties of YI in the FYI.

POSTER #17

Assessing zooplankton using a ZooSCAN and nets: latitudinal gradients in size spectra and diversity driven by temperature and chlorophyll a

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In the Southern Ocean food web, zooplankton occupy a key position in the overall structure and functioning of the ecosystem. Zooplankton communities are very susceptible to change, particularly in a dynamic environment that is expected to experience change through warming, increased storms, and changes in sea ice cover. Size spectra slopes provide a simple way to compare how different habitats are affected by key environmental variables such as temperature and primary productivity. In this context, it is becoming increasingly important to understand how the size spectra of planktonic communities will respond to environmental changes. The ZooScan Integrated Imaging System was deployed to derive empirical relationships between zooplankton size structure and taxonomic composition over a latitudinal gradient of the Southern Ocean, from the subantarctic to south of the Polar Front. Linear mixed models were developed for Normalised Biomass Size Spectra (NBSS) slopes of the zooplankton community in the Indian sector of the Southern Ocean. These revealed that temperature has the most significant effect on the abundance of the population, while primary productivity was most significant for the size spectra. However, despite there being clear differences in the diversity of zooplankton across the sites, these changes were not reflected in the slopes of the size spectra. Our study, which focused on the whole community, found that the general shape and slope of the NBSS did not vary across the wide geographical and thermal range sampled in the study. We conclude that when you consider the whole zooplankton community, the effect of temperature is not as significant as food availability.

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Merged Session 3 = Southern Ocean plankton: productivity, diversity, food-web dynamics, time-series and biogeochemistry

POSTER #18

Seasonal and interannual changes of chlorophyll-a (Chl-a) in the different frontal regions of the Southern Ocean

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The Southern Ocean (SO) plays a pivotal role in the global carbon cycle, and its primary production significantly contributes to oceanic carbon uptake. Chlorophyll-a (Chl-a), an indicator of phytoplankton biomass, offers crucial insights into the physical and biological processes occurring in the SO. This study aims to investigate the seasonal and interannual variations of Chl-a in the five frontal regions of the SO, defined by the areas between the Northern Boundary (NB) and Sub Antarctic Front (SAF); SAF and Polar Front (PF); PF and Southern Antarctic Circumpolar Current Front (SACCF); SACCF and Southern Boundary (SB); and SB and the Antarctic Coast (defined by SCAR).

To achieve this, we utilized satellite data from the Global Ocean Colour (GlobColour) satellite-derived monthly Level 4 (L4) Chl concentration products spanning from 1998-2022, publicly available from the Copernicus Marine Environment Monitoring Service (CMEMS) website. We identified the frontal regions using the two front limit data proposed by Park and Durand (2019), available at SEANOE.

Our findings reveal that the frontal region between the Antarctic coast and Southern Boundary displayed the highest (0.72 mg m-3) Chl-a concentration, while the region between the PF and SACCF had the lowest (0.13 mg m-3) concentration. We observed a statistically significant difference in Chl-a concentrations amongst the five regions (regionsF (4, 1495) = 17.17, p<0.01) and seasons (seasonsF (3, 1496) = 530.01, p<0.01). Furthermore, we noted significant seasonal variability, with maximum Chl-a concentration (0.30 ±0.05 mg m-3) during the austral summer months (Dec, Jan & Feb) and minimum (0.18±0.04 mg m-3) during the winter (Jun, Jul & Aug). We also observed interannual variability, with a non-significant positive trend (~0.001 mg m-3/year) in Chl-a concentration across all frontal regions.

Further studies will assess the spatial and temporal variability within the frontal region and their relationship with physical parameters (e.g., SST) and large-scale climate drivers.

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POSTER #19

More than 20 years of zooplankton data from the deep Southern Ocean

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Despite playing an important role in the food web and carbon cycle of the Southern Ocean, zooplankton biodiversity and dynamics in subsurface waters remain largely understudied. Our understanding of temporal variability in the zooplankton community is hampered by logistical constraints that come with working in this remote oceanic region of the planet. Here, we present a long-term time-series of zooplankton swimmers intercepted by sediment traps; tools that are usually used to measure time-series in downward carbon flux. Swimmers are organisms that enter the traps and are subsequently preserved. At the Southern Ocean Time Series (SOTS) site (47°S, 140°E) in the subantarctic zone, sediment traps have been deployed in the meso- and bathypelagic zone since 1997, resulting in one of the longest time-series for deep-sea zooplankton. Analysis of the archive from 1997-2020 indicates that the zooplankton community was dominated by copepods, amphipods, and pteropods, and abundance and diversity decreased with depth. For most taxa, no significant seasonal increase in abundance during summer was found. Moreover, large influxes of swimmer biomass were caused by amphipod swarms entering the traps, with a potential negative impact on particulate organic carbon flux that requires further investigation. In addition, an increased number of pyrosomes (colonial tunicates) points toward an increased inflow of subtropical waters of the East Australian Current into the subantarctic zone. Finally, we present biases and opportunities for using sediment traps to collect deep-sea zooplankton community data, as well as potential community shifts caused by climate change in the Southern Ocean.

POSTER #20

Validation of the SGLI chlorophyll a concentration in the Southern Ocean

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The Southern Ocean (SO) comprises ~10% of the global ocean. Phytoplankton living in the SO plays an important role in the global carbon cycle and supports the Antarctic marine ecosystems, including fishery resources such as krill, toothfish, and ice fish. Satellite ocean color sensors effectively measure phytoplankton chlorophyll a (chl.a) and primary production in harsh SO environments. The second-generation global imager (SGLI) aboard the global change observation mission-climate (GCOM-C) satellite has 250 m spatial resolution in coastal regions, including waters in the Antarctic sea ice zone. Thus, SGLI can increase opportunities to detect chl.a in the SO, whose optical properties are known to be unique. However, cloud cover and sea ice, which induce noises by inter-channel sub-pixel misalignment, adjacent effect and stray light, interfere with ocean color observations in the SO. In this study, we validated chl.a concentration from the SGLI, and attempted to apply an index of ice contamination using a band-ratio threshold to acquire more accurate chl.a data.

In-situ chl.a concentrations (n=169) determined with ultra-high performance liquid chromatography (U-HPLC) were used for the validation of the SGLI data. We obtained eight match-up data within six hours of a time window, and two out of them showed large errors: the relative and absolute errors were >70% and >0.2 mg m-3, respectively. The anomalous data were found at the edges of clouds and sea ice. The level-2 flags of the SGLI data indicated that the failures were caused by atmospheric

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correction and/or ice contamination. An ice contamination threshold using in-situ water-leaving reflectance in the SO was consistent with the evidence that the absorption coefficient of colored organic matter (CDOM) was lower than that in the Arctic Ocean. Although we need a further collection of such match-up data, our results suggest that the SGLI can accurately estimate chl.a in the SO with 250 m spatial resolution, excluding erroneous data near ice edges using the band-ratio threshold.

POSTER #21

Manganese and iron requirements differ between Southern Ocean diatoms

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Southern Ocean phytoplankton can be limited by low concentrations of the trace metals iron (Fe) and manganese (Mn). These limitations directly impact the strength of the biological carbon pump that transfers carbon from the atmosphere into the ocean through photosynthesis. However, little is known about the interspecific differences in Southern Ocean phytoplankton Fe and Mn requirements or how these requirements will be modified by the rapid environmental changes occurring in the Southern Ocean.

Manganese is an essential micronutrient used in the oxygen evolving complex of photosystem II and in the scavenging of reactive oxygen species. Following the recent discovery of incredibly low dissolved and particulate Mn concentrations in the Australian sector of the Southern Ocean (GEOTRACES-GS01), we investigated regional differences in phytoplankton Fe and Mn requirements. We cultured four Southern Ocean diatom species: a sea-ice species (Fragilaria sp.), a polar species (Proboscia sp.) and two subantarctic species (Lennoxia sp. and Fragilariopsis sp.) under different Fe and Mn concentrations, and we evaluated how their specific trace metal niches differed.

We observed a low Mn requirement but high Fe requirement for the sea-ice diatom, while the polar diatom species had low requirements for both trace metals (e.g., both species grew under the calculated free Mn ion concentration of 10-11.69 M). In contrast, the two subantarctic species displayed a very narrow range of 'low Mn concentrations' allowing growth, and hence became

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abruptly limited by Mn (no growth at 10-11.69 M of free Mn ions). Surprisingly, the polar diatom showed signs of stress relieve when both metal concentrations were decreased, suggesting competitive inhibition may occur between Fe and Mn. Overall, these results provide evidence of highly specific trace metal niches associated with each phytoplankton species, possibly related to the different biogeochemical conditions they inhabit. These results highlight the need to better understand the trace metal requirements of key Southern Ocean species and improve their parameterization within biogeochemical models aiming to predict the evolution of the ocean carbon cycle.

POSTER #22

Diversity of siderophore-producing bacteria and siderophores in the photic zone of the Indian sector of the Southern Ocean.

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Siderophore producing bacteria were screened and isolated from three depths (surface, deep chlorophyll maxima (DCM) and 200 m) at 4 locations in the Indian sector of Southern Ocean (ISO), tested for siderophore production and identified using Sanger sequencing method. For the distribution of siderophores in seawater, 100 L of seawater from the same depths of these stations was also filtered through 0.2 μM membrane filters (Pall, USA), passed through XAD-16 resin column, and then back extracted using methanol. Select siderphore producing bacterial isolates were also grown to characterize their siderophores. Siderophores were identified after analyzing in LC-QTOF-MS. Overall, a total of 173 bacterial isolates tested positive for siderophore production from ISO. These isolates belonged to three phyla namely Actinobacteria, Firmicutes and Proteobacteria. The isolates produced 10 to 55% siderophores and many of the isolates were common in the diverse sampling locations. Select isolates, namely Enterococcus casseliflavus, Psychrobacter piscatorii, and Psychrobacter pocilloporae from ISO that produced hydroxamate type siderophores were cultured for siderophore characterization. All these isolates produced more than one type of siderophores. Siderophores like Snychobactin A, Snychobactin B, Snychobactin C, Itoic acid ethyl ester, Rhizobactin, Fusarinine, Avenic acid, Mycobactin, Cepabactin, Dimethyltriornichin, Dimerum acid, Putrebactin, Ferrioxamine X2, and Ferrioxamine X3 were extracted, purified and identified from these select cultures. The diversity of the siderophore bacteria,

their siderophores and naturally occurring siderophores is discussed in context to their spatial distribution and the oceanographic conditions.

Merged Session 4 = Distributed research efforts from the Scotia Arc through the West Antarctic shelf seas

POSTER #23

Radiocarbon constraints on carbon release from the Antarctic ice sheet into the Amundsen Sea Embayment

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The Amundsen Sea Embayment in West Antarctica is experiencing rapid ice mass loss, resulting in biogeochemical changes via altered nutrient and organic matter supply. However, organic carbon released from melting ice has not yet been accurately quantified. In this paper, we have integrated new dissolved organic carbon (DOC) data obtained close to the melting Dotson Ice Shelf with published radiocarbon (Δ14C) data on sinking and suspended particulate organic carbon (POC), sedimentary OC, DOC and dissolved inorganic carbon to quantify the effect of ice melt to the carbon cycle. Elevated DOC concentrations in deep water near the Dotson Ice Shelf indicate the transport of carbon sources from the ice shelf to the water column at a rate of 4.6 ± 2.0×1010 g C yr−1. Furthermore, Δ14C-DOC measurements suggest there is a possible dark chemoautotrophic production under the influence of meltwater input. The vertical profile of Δ14C in the sedimentary OC from the Sea Ice Zone and the edge of the Dotson Ice Shelf demonstrates the presence of aged organic carbon sources during warm episodes at ~11.5 and 15.9 ka BP. Our study indicates that deep water is not only affected by OC discharge from meltwater but also by biological processes due to altered nutrient inputs. Limited data hampers a precise assessment of the influence of meltwater on the carbon cycle. Further sampling in front of the Dotson Ice

Shelf will be beneficial to enhance our understanding of the role of Antarctic ice sheet melting in the downstream ecosystem.

POSTER #24

Spatial variations in the sea ice-mixed layer depth relationship in the West Antarctic Peninsula

Mr Milo Bischof[1], Dr Daniel Goldberg[1], **Dr Sian Henley**[1], Dr Neil Fraser[2]

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Sea ice plays an important role in determining mixing conditions in the upper-ocean. This is due to freshwater and salt fluxes across the ice-ocean interface related to sea ice formation and melt, as well as a moderation of the mechanical forcing from wind acting on the ocean surface. In turn, water column structure and mixing conditions in the upper ocean are vital factors shaping the environment in which biological production occurs. With sea ice conditions projected to undergo large changes over the course of the century, understanding the relationship between sea ice and upper-ocean mixing is crucial for understanding the impacts of climate change on biological productivity in Antarctic marine systems. Here we present an analysis of sea ice-mixed layer depth relationships during a 40-year regional sea ice-ocean simulation of the West Antarctic Peninsula (WAP) and Bellingshausen Sea, a highly biologically productive region undergoing large present-day changes in climate. The relationship between winter sea ice and spring mixed layer depth shows clear differences on and off the WAP continental shelf, with decadal variations in the location of the boundary between negative and positive correlations. These results are used as a starting point to explore mechanisms that might give rise to regional differences in the sea ice-mixed layer depth relationship in the WAP.
We discuss the nonlinear relationship between sea ice concentration and momentum flux into the ocean; the transport of sea ice within our model domain; the timing of seasonal processes in different regions of the WAP; and the role of Circumpolar Deep Water on and off the continental shelf, as well as the impacts of these factors on the wider Antarctic marine environment.

POSTER #25

Atmospheric Forcing needs for Simulation of the Ocean Processes around the Antarctic Peninsula

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Simulating ocean processes on the shelf near the Antarctic Peninsula requires special consideration due to the rugged bathymetry, steep orography, strong wind forcing, and a short ocean horizontal dynamical scale. A high resolution (1.5 km grid spacing) ocean model, based on ROMS, has been developed to analyze physical and biological processes in the ocean on the west side of the Antarctic Peninsula (WAP). These simulations have been compared to observations from a project (SWARM) that studied the circulation dynamics associated with the Palmer Deep canyon near Anvers Island; a persistent biological hotspot, as shown by known penguin foraging locations. An extensive observing campaign was carried out during summer 2019/2020 to observe the ocean physical and biological characteristics of the area.

Two atmospheric products provide forcing over the model domain: the ERA5 reanalysis (~ 30 km horizontal resolution) and archived forecasts from the Antarctic Mesoscale Prediction System (AMPS: Grid "2" at 8 km horizontal resolution). Wind observations were available from two AWS stations situated on islands ~21 km apart that bracket the northern end of the canyon. Orography of Anvers Island (upwind of the canyon) often causes significant difference in the winds at the two AWS stations.

Both wind products represent the daily averaged wind variability of the AWS stations over summer 2019/2020. However, the ERA5 winds are significantly weaker over the canyon compared to AMPS winds. AMPS winds were also better represent temporal variability in the difference in wind speed between the two AWS stations.

Model Lagrangian drifters backtrack where water parcels originate that influence the Palmer Deep area. Higher resolution winds are able to represent stronger alongshore winds near the coast that are due to orographic steering (the higher resolution atmosphere model better represents coastal orography which better represents the orographic steering). These stronger, narrow coastal winds drive narrow coastal currents which are better able to move ocean properties around this domain. Stronger winds also create deeper ocean mixed layers which allow better representation of summer primary production. We plan to use this ocean model to explore several biological hot spots along the WAP, many located in near-coastal environments which will be better represented with higher resolution AMPS winds.

POSTER #26

Spatio-temporal variations and impact factors of the Amundsen Polynya, Antarctica

Mr. Hongtao Shuai[1], **Dr Jiuxin SHI**[1], Dr. Saisai Hou[1], Mr. Chunhu Xie[1]

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Amundsen Polynya (AP) forms in the coastal sea to the west of the Thwaites Fast-ice Tongue (TFT) in Amundsen Sea (AS) during winter. As the fourth largest coastal polynya in the Antarctica, AP's extensive ice production and associated brine rejection may affect the modified Circumpolar Deep Water in the bottom layer in AP and then the melting of ice shelves in AS,

Using the thin ice thickness and ice production rate data retrieved from satellite microwave radiometer data, we investigate the spatio-temporal characteristics of the AP during 2003-2010 and 2013-2020. Based on the atmospheric reanalysis data, the influence of wind on the area and ice production of the polynya is further discussed. In addition, with the help of satellite remote sensing visible and synthetic aperture radar images and the data of fast-ice around the Antarctic, we analyze the effects of fast-ice and icebergs on the polynya.

In general, there is a good correlation between the winds over AP and AP's area, as well as its ice production. The easterly component of wind dominates the change of AP area by regulating the transport of sea ice in the polynya while the southerly component of wind carries the cold air from the land along coast and intensifies the heat loss at the AP surface, which is the decisive factor for the increase of the ice production in AP. In addition, cyclone transit also affected the evolution of the polynya by changing the winds over AP. When AP is controlled by the southern part of the cyclone, the wind direction over the polynya is conducive to the easterly, which is beneficial to increase AP's area. When the AP is controlled by the west of the cyclone, the wind direction over the polynya is conducive to the southerly, which is beneficial to increase the ice production in AP.

The morphology of TFT at the east side of AP had changed significantly during the study period. Iceberg B22a, which was originally calving from the front of Thwaites Glacier Tongue (TGT), grounded at 108.9 ° W, 74.1 ° S for 10 years after it drifted northward during 2011-2012. During and after B22a's drifting, a large number of small icebergs calved from TGT front, then moved northward and finally grounded at ~500m isobath on the east side of the Beer Bank, resulting in a fundamental change of the TFT's shape after 2012. This change of AP's ice barrier might result in the area and ice production of AP in 2013 reached their maxima in the past 16 years.

Observations to improve predictions of Southern Ocean ecosystems in the global context

POSTER #27

iAtlantic – Integrated Assessment of Atlantic marine ecosystems in space and time

Mr Patrick Schwarzbach

Started in 2019, iAtlantic is the world's first program focusing on an oceanwide approach analyzing health, stability, distribution, vulnerability of and connection between ecosystems. The project includes 12 observation areas in the Atlantic, spread from the south east coast of Greenland, to the west coast of Europe and Africa, the east coast of South America, as well as coast of North America and the central Atlantic basin. The main goal of iAtlantic within an intense international collaboration and knowledge exchange is, to find out key drivers of pressure on ecosystems. Measuring abiotic factors (seawater circulation patterns, temperatures, acidity, oxygen levels) on the underwater biosphere, iAtlantic aims to reveal tipping points for deep ocean ecosystems and to identify the most important stressors to determine the resilience of the ecosystems. For that reason, a systematic and standardized ocean observing strategy is applied, allowing a short-, medium- and long-term assessment using deep ocean observation techniques, robotics and imaging technology as well as genomic and ecological time series. Due to intercontinental extend, Atlantic regions are investigated by an international teams during 30 expeditions enhancing human and technological capacities and interactions.

Roberts J.M., Devey C.W., Biastoch A., Carreiro-Silva M., Dohna T., Dorschel B., Gunn V., Huvenne V.A.I., Johnson D., Jollivet D., Kenchington E., Larkin K., Matabos M., Morato T., Naumann M.S., Orejas C., Perez J.A.A., Ragnarsson S.Á., Smit A.J., Sweetman A., Unger S., Boteler B., Henry L.-A., 2023. A blueprint for integrating scientific approaches and international communities to assess basin-wide ocean ecosystem status. Communications Earth & Environment 4, 12, https://doi.org/10.1038/s43247-022-00645-w.

Observations to understand ocean dynamical processes

POSTER #28

Exports of Weddell Sea Deep Water through Orkney Passage

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Orkney Passage is a deep gap in South Scotia Ridge, with a sill depth of around 3650 m, and is a major export route of Weddell Sea Deep Water, a precursor of globally important Antarctic Bottom Water, from the Weddell Sea to the Scotia Sea. Since 2004, moorings have been deployed here, with full coverage across the passage since 2011. We present time series from these moorings showing the variability in WSDW and LWSDW exports from 2011-2021, and their relation to the variability of deep water masses upstream, local mixing processes, and regional and global climate variability.

POSTER #29

Using mooring and model data to estimate the volume transport of Antarctic Bottom Water

Dr Kathryn Gunn[1,2], Dr Steve Rintoul[2], Professor Matt England[3], Dr Melissa Bowen[4]

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Antarctic Bottom Water (AABW) is a key component of the ocean circulation, providing the deep oceans with oxygen and sequestering heat. Many studies have highlighted rapid and widespread changes in the volume of AABW, with implications for global ocean circulation. However, observations around the margins and in the deepest parts of the Southern Ocean are sparse in space and time. Estimates of volume transport are especially limited. This poster examines if and how mooring, model, and repeat hydrographic data can be used to provide circumpolar estimates of volume transport.

POSTER #30

Investigating the dynamics and exchanges across the ice-ocean interface in artificial sea ice

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According to the current studies, there will be a significant decrease in sea ice in both polar regions, which is crucial to the global climate system, since sea ice itself plays a major role in affecting the interaction between the ocean and the atmosphere by insulating the upper portion of the ocean from the polar atmosphere.

This study specifically focuses on the interaction occurring between the ice and the ocean.

Investigation of the ice-ocean interaction involves focusing on the internal structures present within the sea ice, such as brine channels, and how these internal structures affect the dynamic processes occurring during sea ice growth.

Dynamic in-situ process analysis on Antarctic sea ice is difficult, since currently most available techniques merely provide post-mortem information of the final sea ice sample, without providing further information on the dynamic processes during sea ice growth. Furthermore, certain techniques are only able to provide information on the mushy ice layer, while neglecting additional information on the water below the sea-ice interface, thus not allowing for a complete understanding of the sea ice dynamics. By employing schlieren and direct optical techniques, both the ice layer and underlying water can be visualised and investigated.

Since field experiments pose an additional issue relating to the difficulty of isolating external variables and performing high-resolution small-scale investigations over time, this study involves the performance of laboratory-based artificial sea ice experiments within a quasi-2D Hele shaw cell system in a temperature-controlled sub-zero environment to investigate the dynamics at a small scale across the ice-ocean interface.

Schlieren and direct light optical techniques are used and coupled with Digital Image Processing (DIP) and optical flow algorithms to provide a non-invasive way to visually and quantitatively investigate the dynamics and brine channel velocity during sea ice growth at freezing temperatures ranging between -5 degrees and -20 degrees Celsius.

This study presents a novel outlook on quasi-2D sea ice investigation and analysis methods to investigate the dynamics associated with brine channels within sea ice.

POSTER #31

Observing and modeling circulations in Prydz Bay, Antarctica

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An objective interpolation method is applied on the data of Acoustic Doppler Current Profiler (ADCP) and Lowered Acoustic Doppler Current Profiler (LADCP) obtained by the 31st Chinese National Antarctic Research Expedition from February 5 to March 2,2015, to construct a three-dimensional structure of circulations in Prydz Bay. Two inflows are found in the results, a southwestward flow along east coast and a southeast flow along the east flank of Prydz Channel. They converged into the Prydz Bay Eastern Coastal Current (PBECC) that flows along the front of Amery Ice Shelf (AIS). After splitting a small northward branch at 73°E, PBECC continue flowed along AIS front and then left from the bay along east flank of Fram Bank after creating a small cyclonic gyre in Mackenzie Bay. A cyclonic gyre occupied the Prydz Basin, consisting of the southeast inflow along east flank of Prydz Channel, PBECC along east coast and eastern AIS front, and the northward branch splitting at 73°E.

The Regional Ocean Modeling System (ROMS) is employed to create a three-dimensional numerical model of the summer circulation in the Prydz Bay region, Antarctica. Consistent with the above circulation structure, the simulated current field illustrates the major features of the Prydz Bay circulation, including the Antarctic Slope Current (ASC) along the continental shelf break, the cyclonic Prydz Bay Gyre, and the PBECC. The effects of grounding icebergs D15 and B15 on the circulation in Prydz Bay are investigated via numerical simulations. The results indicate that these giant grounding icebergs substantially affect the flows into and within the bay, which may differ with the different grounding locations. As grounding iceberg D15 is located close to the southwestern part of the West Ice Shelf (WIS), it cuts off the coastal current along the outer edge of the WIS, and the ASC can only enter Prydz Bay from the west side of iceberg D15, whereupon it becomes a main source of the PBECC. Iceberg D15 also weakens the circulation in the bay in general. The relatively small iceberg B15 entered Prydz Bay from 2007 to 2009 and grounded on the southwestern section of the Four Ladies Bank. The numerical experiments indicate that iceberg B15 guides the ASC flowing into the bay around its west side and reduces the width of the inflow on the eastern side of the Prydz Bay Channel. The grounding of iceberg B15 has also led to adjustments of the circulation within the bay, among which the most significant is that the outflow along the western flank of Fram Bank has shifted to the west and become more intensive.

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POSTER #32

Nighttime Cool Skin Effect Observed from Infrared SST Autonomous Radiometer (ISAR) and Depth Temperatures

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The nighttime ocean cool skin signal deltaT [defined as skin sea surface temperature (SSTskin) minus depth SST (SSTdepth)] is investigated using 103 days of matchups between shipborne Infrared SST Autonomous Radiometer (ISAR) SSTskin and water intake SSTdepth at 7.1–9.9 m depths, in oceans around Australia and in the Southern Ocean. Before data analysis, strict quality control of ISAR SSTskin data is conducted and possible diurnal warming contamination is carefully minimized. The statistical distribution of deltaT, and its dependencies on wind speed, heat flux, etc., are consistent with previous findings. The overall average deltaT value is -0.23 K. It is observed that the magnitude of the cool skin signal increases after midnight and a coolest skin offset (with an average value of -0.36 K) is found at around dawn. The dependency of deltaT on SST conditions is observed. Direct warm skin events are discovered when the net heat flux direction is from the atmosphere to the ocean, which is more likely to occur at high latitudes when the air is very humid and warmer than the SST. In addition, several cool skin models are validated: one widely used physical model performs best and can capture most skin-effect trends and details; the empirical models only reflect the basic features of the observed deltaT values. If the user cannot apply the physical model (due to, e.g., the algorithm complexity or missing inputs), then the empirical parameterization in the form proposed in a 2002 study can be used. However, we recommend using a new set of parameters, calculated in this study, based on much more representative dataset, and with more rigorous quality control.

Observing, mapping and monitoring Antarctic seafloor fauna and their habitat

POSTER #33

The Antarctic Seafloor Annotated Imagery Database (AS - AID) – an international collaboration to map Antarctic seafloor fauna

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Marine images are a comparatively cost-effective tool to collect data on seafloor organisms, biodiversity and habitat morphology. However, annotating these images to extract detailed biological information is time-consuming and expensive, and publicly available datasets of expert annotated seafloor images are rare. Here, we present the fully reproducible Antarctic Seafloor Annotated Imagery Database (AS-AID), a result of a multinational collaboration to collate and annotate regional seafloor imagery datasets from 19 major Antarctic research cruises between 1985 and 2019. We have collated more than 100,000 georeferenced downward facing seafloor images, of which a subset of 3,599 has been annotated. Annotations are based on CATAMI (Collaborative and Automated Tools for Analysis of

Marine Imagery), have been expert reviewed and, because the location of each annotation in each image is available, annotations can be easily viewed, reviewed and customised to suit individual research priorities.

This global open-source database establishes a foundation to which annotations can be added in the future. AS-AID can be used to investigate species distributions, community patterns and can be used to train neural networks for automatically detecting and annotating marine fauna.

POSTER #34

Small but important: differences in ice-cover regimes have a greater impact on meiofauna than on macrofauna communities

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Changes in sea-ice cover in the Southern Ocean (SO) have a major impact on sensitive benthic organisms as they rely on food input from primary production and particle flux to the seafloor. This correlation was found for meio- and macrofauna separately. To date it was unknown how environmental changes affect the soft-bottom benthos as a whole. We investigated, the relationship between ice-cover regime, food input, and the combined composition of meio- and macrofauna communities. Five geographical regions were sampled during RV Polarstern-expeditions PS81 and PS96, representing different ice-cover categories according to their summer sea-ice cover derived from remote sensing: none (Drake Passage), irregular (Bransfield Strait), seasonal (northwestern Weddell Sea), high (South Filchner Trough), constant (North Filchner Trough). Sediment samples for fauna and environmental analyses (grain size, TOC, TN, pigment content) were collected with a multicorer. Water-column data (temperature, salinity, chlorophyll a) were derived from CTD samplings. The regions differed significantly in primary-production–related properties in the water column and food availability at the seafloor. Meiofauna communities differed significantly between almost all ice-cover categories, whereas macrofauna or the combined meio- and macrofauna communities differed only between some regions. Environmental drivers explained > 66% of the variation among different communities and differed for the faunal size classes: for meiofauna composition (84.2%), 1-year ice cover (34.7%) and chlorophyll a (20.2%) were most important, whereas 1-year ice cover (21%), chlorophyll a (11%), and TOC (10.9%) were decisive drivers for macrofauna composition (66.6%). Our findings highlight a stronger relationship with sea-ice cover for the less studied meiofauna communities compared to macrofauna. We propose to use ice-cover classifications to predict meiofauna composition and the distribution of ecologically relevant taxa. Besides the recent ice sea-ice cover, though, the quantity of available fresh food (approximated via chlorophyll a) in the sediment is most reliable for explaining endobenthic community patterns and should always be included in the set of directly measured benthic parameters. Furthermore, we recommend including meiofauna community information in future assessments concerning the impact of environmental changes on SO ecosystems.

Plankton diversity, food web dynamics and Biogeochemical cycle in the Southern Ocean

POSTER #35

Cryptophytes: An emerging algal group in the rapidly changing Antarctic Peninsula marine environments

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The western Antarctic Peninsula (WAP) is a climatically sensitive region where foundational changes at the basis of the food web have been recorded; cryptophytes are gradually outgrowing diatoms together with a decreased size spectrum of the phytoplankton community. Based on a 11-year (2008-2018) in-situ dataset, we demonstrate a strong coupling between biomass accumulation of cryptophytes, summer upper ocean stability, and the mixed layer depth. Our results shed light on the environmental conditions favoring the cryptophyte success in coastal regions of the WAP, especially during situations of shallower mixed layers associated with lower diatom biomass, which evidences a clear competition or niche segregation between diatoms and cryptophytes. We also unravel the cryptophyte photo-physiological niche by exploring its capacity to thrive under high light stress normally found in confined stratified upper layers. Such conditions are becoming more frequent in the Antarctic coastal waters and will likely have significant future implications at various levels of the marine food web. The competitive advantage of cryptophytes in

environments with significant light level fluctuations was supported by laboratory experiments that revealed a high flexibility of cryptophytes to grow in different light conditions driven by a fast photo-regulating response. All tested physiological parameters support the hypothesis that cryptophytes are highly flexible regarding their growing light conditions and extremely efficient in rapidly photo-regulating changes to environmental light levels. This plasticity would give them a competitive advantage in exploiting an ecological niche where light levels fluctuate quickly. These findings provide new insights on niche separation between diatoms and cryptophytes, which is vital for a thorough understanding of the WAP marine ecosystem.

Processes and ecosystem response of the Southern Ocean

POSTER #36

Carbon fluxes in the subantarctic zone revealed by multi-year biogeochemical-Argo floats and sediment trap observations

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The high latitude Southern Ocean exerts an important control on the global climate. In previous work, we built a two decade hindcast of the sea surface partial pressure of CO2 (pCO2), confirming that the subantarctic region near the Southern Ocean Time Series mooring station (SOTS; around 47°S, 142°E) is a carbon sink. By decomposing the pCO2 we found that the seasonal variability in pCO2 is mainly driven by the biological component. This may imply that the biological carbon pump (BCP) plays a vital role in sequestering carbon. The BCP is typically considered to be mostly a gravitational pump, but recently other pathways contributing to the flux have been discussed. Ongoing research uses BGC-Argo floats to understand and quantify the relative contributions of the gravitational, mixed layer and eddy subduction pumps in the subantarctic region, near the SOTS. Since 2011, twelve BGC-Argo floats equipped with bbp sensors have passed through the SOTS region and thus produced four periods with intense, year-round sampling. Particulate organic carbon (POC) concentration, estimated from BGC-Argo backscatter measurements, is used to quantify the carbon flux in different pathways. By comparing it to sediment trap mass flux and particle composition data (1000m, 2000m and 3800m) at the SOTS site, the carbon sequestration efficiency of each mechanism is investigated. These data provide an important opportunity to understand the seasonality of different carbon pumps in the subantarctic zone.

Reshaping long-term observatories with focus on Antarctic and Southern Ocean: Drivers, implementation and outcome

POSTER #37

Opportunities and challenges in establishing a polar data centre

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The Southern Hemisphere polar region is a system of interconnected physical and ecological components comprising the Antarctic continent, sub-Antarctic islands, the Southern Ocean and the deep ocean basins surrounding South Africa. The Antarctic region is hence climatically, ecologically and socio-economically linked to South Africa, and the vast range of disciplines require a holistic approach. The vision of the recently established South African Polar Research Infrastructure (SAPRI) is to facilitate balanced and transformed research across polar disciplines, and to maintain and further expand the world-class, long-term observational research infrastructure and datasets already established in South African polar and oceanographic research. SAPRI will ensure coordination of South African polar and oceanographic research by providing seamless access to existing and new research infrastructure required to develop and enhance long-term observations. A model will be created in which the scientifically established lines of research that rely on the observations of essential variables will be transformed into long-term monitoring structures. SAPRI takes the form of a unified but distributed infrastructure that will coordinate, combine, and strengthen existing capabilities by building on the suite of observatories, sentinel sites, and research platforms already established and maintained by the

South African National Antarctic Programme community. Data across disciplines will be handled by the SAPRI Data Centre, which will be designated as the National Antarctic Data Centre for South Africa and will maintain current best practices in relation to its repository management functions and related systems, and best international practices will be adopted for data management. A focus of the SAPRI Data Centre will be on homogenising different data streams, product dissemination and communication. This presentation will outline plans for these goals along with the challenges faced, and the work planned to develop data pathways to ensure long-term observations are enhanced. An important component of the SAPRI mission is coordination and collaboration with the international Antarctic community, and we welcome engagement and discussion with the SOOS community in this regard.

Southern Ocean sea ice variability in a warming climate: Observations and modelling approach

POSTER #38

Antarctic coastal exposure to sea ice-free (open-ocean) conditions – Change and variability since 1979

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Change in the exposure of Antarctica's 18,000 km of coastal margins to sea-ice free (open-ocean) conditions, including greater wave energy, has consequences for the stability of ice shelves, the coverage and duration of landfast sea ice, nearshore ecosystems, and logistical operations. Here, we introduce "Coastal Exposure Length" (CEL) – a new climate and environmental index and metric derived from the long-term satellite sea-ice concentration record dating back to 1979. This enables complete daily circumpolar mapping (at 25 km resolution) and quantification of the amount (extent) of Antarctic coastline not protected by a pack-ice "buffer" offshore i.e., exposed to the open Sothern Ocean and waves. The time series reveals previously-unknown mean regional patterns of exposure around Antarctica, distinct seasonal and regional trends, and high variability since 2012. The motivation is to fill a major current gap in our knowledge on Antarctica's vulnerable coastal environment, towards (1) gauging its response to changing climatic conditions and (2) improved modelling of its current/recent and likely future state. We also present initial findings from a by-product of the CEL algorithm, namely coastal polynya distribution and size. The new time series complement the widely-used sea-ice concentration, extent and seasonality time series and analyses derived from the same base dataset.

POSTER #39

Variability of Circumpolar Deep Water transport across the Weddell Sea Ice Shelves

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The Circumpolar Deep Water (CDW) is the main heat source for the Antarctic margins. Its onshore transport influences key processes that have a global impact, such as the melting of Antarctic ice shelves and the process of Antarctic Bottom Water (AABW) formation. The warming observed in some regions of the Antarctic margins has been directly linked to the inflow of the CDW onto the continental shelf, which has also shown a shoaling and warming trend. As a result, these regions are also those that experienced greatest ice-shelf volume loss. Ice shelf collapse threatens to reduce buttressing and accelerates glacial flow seaward. In addition to its contribution to sea level rise, the ice loss also increases the freshwater flux into the Antarctic coastal seas, modifying the properties of the Antarctic Shelf Bottom Water (ASBW) and, consequently, AABW formation. Despite its importance, the study of processes connected to Antarctic coastal dynamics has been challenging due to both coarse observational data products available and the numerical challenge of integrating processes that occur at different scales. However, the recent development of high-resolution oceanic products can significantly improve our understanding about this region and its response to climate changes. Here, we propose to investigate the variability of the CDW transport at the edge of the Weddell Sea ice shelves and assess potential impacts to coastal dynamics. To achieve our goal, we rely on high-resolution results from the Global Ocean Physics Reanalysis 1/12° (GLORYS12V1) product provided by the Copernicus Marine Environment Service (CMEMS).

POSTER #40

Synoptic scale variability of Antarctic sea ice concentration and drift: evidence for increased rotational drift from atmosphere to sea ice

Mr Wayne De Jager[1,2], Mrs Ehlke Hepworth[1,2], Mr Christian Melsheimer[3], Mr Gabriele Messori[4,5,6], **Prof Marcello Vichi**[1,2]

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Sea-ice coverage - and by extension the variability of this coverage - is a key component of the Southern Ocean climate system. While the El Niño–Southern Oscillation (ENSO) and the Southern Annular Mode (SAM) have been shown to influence sea-ice variability, the degree of relative influence of these larger-scale atmospheric modes is debated, and it is becoming increasingly argued that Antarctic sea-ice variability trends are driven by local weather events rather than larger-scale atmospheric features. Here we show how synoptic scale atmospheric features in the Southern Ocean are affecting the underlying ice, and highlight the potential mechanisms driving this change. We characterised synoptic sea-ice variability and cyclone activity in different Southern Ocean sectors using atmospheric reanalyses and a cyclone-tracking algorithm, and then quantified the proportion of extreme sea-ice concentration change engendered by cyclones of different intensities. We find that roughly 40% of the extreme sea-ice variability is caused by extratropical cyclones, with most of it due to the intense cyclones in the eastern sectors and Ross Sea, whereas in the Weddell Sea weaker cyclones and extreme variability are more linked. Together with satellite-derived sea-ice drift data at the daily timescales, we present evidence that sea-ice vorticity

is another useful metric for quantifying dynamical features in Antarctic sea ice; specifically these shorter term changes in the ice-interior driven by local storms. A relatively strong correlation exists between the ice and atmosphere vorticity fields, with a gradual but statistically significant increasing trend between 1991-2020, suggesting an increased rotational momentum transfer from wind to ice over this period. We also comment on the performances of currently available satellite products in detecting daily sea-ice variability, noting that rapid sub-daily changes in the Southern Ocean may be being blurred or averaged out in daily map processing methods.

POSTER #41

Antarctic landfast sea ice: Physical, biogeochemical and ecological significance

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Antarctic landfast sea ice (fast ice) is stationary sea ice that is attached to icebergs grounded in waters up to ~450 m deep and the coast - including ice shelves and other protrusions on the continental shelf e.g., glacier tongues. Fast ice forms in narrow (up to 200 km wide) bands, and can be up to tens of metres in thickness. In most regions, it forms in autumn, persists through the winter and melts in spring/summer, but may remain throughout the summer in particular locations. Despite its relatively limited horizontal coverage (comprising about 4 to 13 % of overall sea ice extent), its presence, variability and seasonality are drivers of a wide range of physical, biological and biogeochemical processes, with both local and far-ranging ramifications for various key parts of the Earth system. Antarctic fast ice has, until quite recently, been overlooked in many studies, likely due to insufficient knowledge of its characteristics, leading to its reputation as a "missing piece of the Antarctic puzzle." In this poster we give a synopsis of the current state of knowledge of the physical, biogeochemical and biological aspects of fast ice, focusing on identifying and suggesting ways to address the gaps in our knowledge. We also consider the potential state of Antarctic fast ice at the end of the 21st Century, underpinned by Coupled Model Intercomparison Project projections.

Understanding the state and variability of Southern Ocean CO2 sea-air fluxes and carbon cycle

POSTER #42

Evaluating the drivers of regional carbon cycle variability and acidification using the Munida Time Series

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While the acidification resulting from the uptake of anthropogenic carbon dioxide by the global ocean is well documented, the drivers of variability that effect acidification rates on regional scales are not well understood. The Munida Time Series (MTS), a repeat transect off the southeast coast of New Zealand, is the longest running record of ocean carbon in the southern hemisphere. 20+ years of MTS observations were used with remotely sensed, meteorological, and oceanographic reanalysis datasets to constrain the physical processes in a surface ocean carbon budget to diagnostically assess the contributions from air-sea gas exchange, surface freshwater flux, physical transport processes, and biological productivity to variability in the mixed layer carbon cycle. The seasonal carbon cycle in this region is dominated by horizontal advection of water higher in dissolved inorganic carbon (DIC) in this western boundary current system where the subtropical front comes near the coast. Advection is balanced by net community production and calcium carbonate production, which maintains the net absorption of atmospheric CO2 at annual flux of 0.84 mole C m-2 y-1, but with apparent sub-to-decadal scale variability in this regional carbon sink. Growth rates in ocean pCO2 exhibit disequilibrium with atmospheric growth over these timescales and appear driven by changes in ocean heat content and circulation as evidenced by concurrent trends in mixed layer CO_2 solubility and advection of DIC. Correcting for changes due to the weakening of DIC advection, we show that these changes have maintained the strength of this regional sink for atmospheric CO_2 by 50% and has resulted in pH that is 0.01 higher that it would have been with no long-term change in circulation. There are strong correlations between decadal variability in the mixed layer temperature and salinity and the El Nino Southern Oscillation and Southern Annual Mode which indicate how regional acidification may be modulated by broader dynamics in the Southern and Pacific Oceans and the sensitivity to basin-scale forcing.

Miscellaneous

POSTER #43

BIO-MATE: A biological ocean data reformatting effort

Ms Kimberlee Baldry[1]

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Biological ocean data collected from ships find reuse in aggregations of historical data. These data are heavily relied upon to document long term change, validate satellite algorithms for ocean biology and are useful in assessing the performance of autonomous platforms and biogeochemical models. There is a need to combine subsurface biological and physical data into one aggregate data product to support reproducible research. Existing aggregate products are dissimilar in source data, have largely been restricted to the surface ocean and most omit physical data. These products cannot easily be used to explore subsurface bio-physical relationships. We present the first version of a BIOlogical ocean data reforMATting Effort (BIO-MATE, https://gitlab.com/KBaldry/BIO-MATE). BIO-MATE uses R software that reformats openly sourced published datasets from oceanographic voyages. These reformatted biological and physical data from underway sensors, profiling sensors, pigments analysis and particulate organic carbon analysis are stored in an interoperable and reproducible BIO-MATE data product for easy access and use.

POSTER #44

Checking the pulse of Antarctica – Can Digital Earth help?

Ms Kimberlee Baldry[1], Dr Alix Post[1], Jonathan Mettes[1], Dr Melissa Fredrigo[2], Norman Muellet[1]

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Earth Observations over Antarctica and the Southern Ocean are critical for understanding changes in the cryosphere, ecosystems and oceans through time. Our ability to observe Antarctica systematically at a continental scale is constrained by difficulties accessing, storing and pre-processing satellite imagery prior to analysis. Some of these challenges are unique to the Antarctic environment, where factors such as cloud masking, reflectivity, prolonged periods of darkness and atmospheric differences in water vapour, aerosol and signal scattering mean that corrections applied to satellite data in other regions of the world aren't representative of Antarctic conditions. A new collaboration between Geoscience Australia and the Australian Antarctic Division, Digital Earth Antarctica, aims to improve access to corrected continental scale satellite data through use of Open Data Cube technology. This initiative builds on work in the international community in developing Open Data Cube platforms, which have been applied in the development of Digital Earth Australia and Digital Earth Africa. The Digital Earth Antarctica platform will provide open access to analysis ready time-series data that has been corrected and validated for Antarctic conditions. It will focus primarily on data from Landsat (optical), Sentinel-1 (synthetic aperture radar) and Sentinel-2 (optical), with other sensors to be added as the capability expands. Digital Earth Antarctica is an ambitious project that will work alongside other international efforts to enhance the accessibility of quality Antarctic Earth Observations.

POSTER #45

Using a circum-Antarctic plankton isoscape to identify areas of importance for carbon export and long-term observation in the Southern Ocean

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The Southern Ocean is a major hotspot for gas exchange, accounting for ~40% of the global ocean CO2 sink, in part due to its biological pump that is driven by complex plankton ecosystems. Using samples collected during the Antarctic Circumnavigation Expedition (ACE) in the austral summer of 2016/2017, we investigated latitudinal gradients in the stable isotope ratios of carbon (δ13C) and nitrogen (δ15N) in surface suspended particulate matter across the different hydrographic zones of the Southern Ocean. Overall, we found that the Southern Ocean has potentially exported almost half of the carbon produced (f-ratio = 43.2±27.3%) during the austral summer of 2016/2017. The regions of largest carbon export were found to be in the vicinity of the (Sub) Antarctic Islands, the Antarctic Peninsula and at the mouth of the Ross Sea (f-ratio = 50-99%), where high abundances of diatoms and elevated nutrient supply were evident. Along with iron availability, phytoplankton community composition emerged as an important driver of the biological pump across the summertime Southern Ocean, with large diatoms dominating regions characterized by high nitrate dependence and elevated carbon export potential. To monitor the anticipated changes in biogeochemical cycling and the phytoplankton community, and their effects on the biological carbon pump, we propose a network of key long-term stations to be included in SOOS, as well as key Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs) that should be measured at each of these stations.

POSTER #46

Coccolithophore communities in the Sub-Antarctic Zone: floristic diversity revealed through long-term sampling

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Coccolithophores are a diverse group of marine, unicellular organisms with the ability to produce intricately-formed exoskeletons of tiny calcium carbonate plates (liths) and thus are intimately linked to global carbon cycles in the ocean. The ability of coccolithophores to perform photosynthesis and calcification means they are central to marine carbonate cycles and can influence ocean-atmosphere CO2 exchange, and export organic and inorganic carbon to the deep ocean.

Whilst the cells are microscopic and require electron microscopy for detailed identification, large oceanic blooms can be seen from space. Coccospheres and liths are well preserved in water samples and deep-sea sediments and they are frequently used to assess biogeochemical processes in contemporary and past populations.

We describe the diversity of coccolithophorid species observed in the Sub Antarctic Zone of the Southern Ocean, a region that plays a disproportionately large role in the uptake and storage of anthropogenic CO2. We highlight the use of multiple, long-term monitoring programs supported by IMOS to collect water and sediment trap samples, and deep sea-sediments to catalogue floristic diversity of coccolithophores in the region. These biodiversity records are important for assessing changes in community composition as a result of environmental change, namely warming and ocean acidification.

POSTER #47

The utility of ongoing seawater δ18O observations in the Southern Ocean

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There is a long history of temperature and salinity observations in the Southern Ocean. Less frequently, parameters such as dissolved oxygen and/or Noble gases are measured, which together with hydrography permits identification of freshwater sources. For this purpose, seawater oxygen isotope measurements have been underutilized. Since δ18O is independent of temperature and salinity, it can be used to understand source mixing of different waters. Glacial meltwater is highly depleted in δ18O, while coastal precipitation is less depleted. Sea ice meltwater is slightly enriched relative to seawater but has a similar effect on salinity as glacial melt and precipitation. The distinct δ18O signature of these different freshwater sources allows us to understand the source of changes in seawater salinity. Here, we present data from 5158 seawater isotope samples – including 3882 new analyses – collected from the Ross Sea to the West Antarctic Peninsula between 1976 and 2020; We trace changes in salinity and δ18O in the Ross Sea across 5 decades, showing an influx of glacial freshwater from the Amundsen Sea as well as from local sources. In the SE Amundsen Sea, where the Pine Island and Thwaites glaciers are rapidly losing mass, we present a time series of glacial meltwater inventories spanning 26 years. Finally, In the Bellingshausen Sea, we demonstrate the utility of seawater δ18O measurements to differentiate meltwater from different ice margins. Seawater δ18O has distinct utility as an adjunct tracer of changes in the Southern Ocean, and its relative ease of sampling and analysis makes a compelling case for its inclusion in the core of SOOS data collection.

POSTER #48

On the Fracture Zones of the Southwest Indian Ocean Ridge: Antarctic Bottom Water and Circumpolar Deep-Water in new observations

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The Indian Ocean supports a vigorous deep meridional overturning circulation, which converts cold, deep, and bottom water originating in the Southern Ocean into thermocline and intermediate water, a major deep upwelling branch of the global Meridional Overturning Circulation. A primary pathway for the southern-originated waters is through the Fracture Zones of the Southwest Indian Ocean Ridge that connects the Crozet Basin in the Southern Ocean to the Madagascar Basin in the South Indian Ocean. Here, we report for the first time concomitant hydrographic, chlorofluorocarbon, and current observations in the four deep fracture zones of the Southwest Indian Ocean Ridge: Gallieni, Atlantis II, Novara, and Melville. These new measurements have been just collected (April-May 2023) as part of the Deep Madagascar Basin Experiment funded by the US National Science Foundation. Here we focus on a slanted section in the southern limb of the Madagascar Basin and parallel to the main axis of the Southwest Indian Ocean Ridge, with additional high-resolution sections within the fracture zones. We find the fracture zones different in terms of water properties and tracers, with Novara presenting an astonishing northward flow below 3500 m (peaking at 50 cm/s). The Novara's deep northward flow is much larger than in the Atlantis II fracture zone (~ 30 cm/s), which was until now considered the main conduit for Antarctic Bottom Water and Circumpolar Deep Water into the Indian Ocean. As the data have been recently collected, we are still analyzing these novel observations and expect to report much more during the symposium.

POSTER #49

Diversity and abundance of prokaryotes in Antarctica: the effect of oceanography in the Bransfield Strait.

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Microorganisms fulfill essential roles in marine ecosystems and their study is essential to understand their functioning. Despite its importance, in Antarctic waters, and particularly in the Bransfield Strait, there is little information about it. This study describes the spatial patterns of abundance and diversity of free-living and particle-associated prokaryotic communities (Archaea and Bacteria) in the Bransfield Strait. Oceanographic conditions were recorded at 13 stations, and in 7 of them the prokaryote community was analyzed at depths between 5 and 1000m. Each sample was separated into 3 size fractions, being able to differentiate free-living prokaryotes (0.2-3μm) from those associated with particles (3-20μm; 20-200μm). Prokaryotic diversity was analyzed by 16S rRNA gene sequencing (75 samples), and abundance was analyzed by flow cytometry. Diversity and abundance varied with depth: a greater abundance of prokaryotes was found in surface waters, and a greater diversity in deep waters. A similar diversity was observed in the three fractions considered, but with significant differences in their specific composition. The variables that most explain the composition of the community are depth (~20%), followed by lifestyle (~16%). The largest number of indicator species was found in deep water, followed by the free-living fraction. The composition of the surface water community is positively related to higher temperature and oxygen concentration, while deep communities were related to higher salinity. Specific

prokaryotic communities were observed based on depth, ecoregion, water mass, and distance from Deception Island. These results show that there are prokaryotic communities that are structured according to the variables considered, and that the deep waters of the Bransfield Strait represent a reservoir of microbial diversity in this Antarctic area.

POSTER #50

Investigating the Role of Coastal Polynya Variability in Modulating Antarctic Ice Shelf Oceanographic Environments

Dr Catherine Walker[1], Dr. Weifeng Gordon Zhang[1], Dr. Helene Seroussi[2], Dr. Divya Allu Peddinti[2], Mr. Yilang Xu[1],[3], Mr. Alan Gaul[1],[3]

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Ice shelves make up almost half of the entire Antarctic coastline, and hold back the flow of inland ice in Antarctica continent; thus they are integral to the overall stability of the Antarctic Ice Sheet. Ice shelves lose mass by two main processes: iceberg calving and basal melting. Temporal and spatial fluctuations in both are driven by various processes, and a major driver of ice shelf melt is the heat provided by the neighboring Southern Ocean. One of the most significant contributors to changes in the ocean's heat content is the presence of sea ice. This project focuses on the effects of coastal polynyas, how they modulate the local ocean environment, and how that environment influences ice shelf basal melting on a continent-wide scale. Understanding the feedbacks between polynya size and duration, ocean stratification, and ice shelf melt, and the strength of those feedbacks, will improve the ability to characterize influences on the long-term stability of ice shelves.

In this effort, observational data, including ice-penetrating radar, altimetry, and in situ hydrographic data, and derived data sets from the Southern Ocean State Estimate (SOSE) project and BedMachine Antarctica, are used in conjunction with ocean (MIT global circulation model, MITgcm) and ice sheet (Ice sheet and Sea-level System Model, ISSM) models to reveal underlying dynamics. Diagnosing and interpreting the pan-Antarctic spatial variability of the polynya-ice shelf interaction are the main objectives of this research, and separates this study from other projects targeted at the interactive processes in specific regions. As such, this research focuses on seven preliminary target sites around the Antarctic coast to establish a framework for interpreting coupled ice shelf-ocean variability across a diverse range of geographic settings. Here, we will present our first year of work on this project, discussing observational results and initial modeling efforts as we begin year two of this project. Specifically, we focus the discussion of our early results around our four main hypotheses: on four main hypotheses: 1) Variations of coastal polynya extent are correlated with those of the ice shelf melt rates, and this correlation varies around Antarctica; 2) Polynya extent modulates a feedback between ice shelf melt and accretion regimes through stratification of local waters; 3) Polynya extent together with seafloor bathymetry regulate the volume of warm offshore waters that reach ice margins; and 4) The strength of the feedback between polynya and glacier ice varies with geographic setting and influences the long-term stability of the glacial system.

POSTER #51

Quantifying Potential Plastic Pollutant Sources and Risks to Penguins on the West Antarctic Peninsula

Dr. Katherine Gallagher[1], Dr Megan Cimino[2], Michael Dinniman[3], Heather Lynch[1]

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Plastic pollution is becoming ubiquitous in the marine environment. Antarctica is often marketed as Earth's final pristine frontier, however, observations of plastic pollution on beaches, in the coastal ocean, and in Antarctic organisms are becoming increasingly common. Increasing human activity, including growing tourism and krill fishing industries along the West Antarctic Peninsula also may serve as increasing sources of plastics to the region. However, the sources of these pollutants from point (pollutants released from discrete sources) versus non-point (pollutants from a large area rather than a specific source) sources are poorly understood. We utilized buoyant simulated particles released in a physical ocean model to quantify plastic loads in the region broadly and around penguin colonies. We also determined possible origins for observed plastics based on data from the Southern Ocean Observing System and Palmer Long Term Ecological Research program. We considered non-point sources of plastic from the Antarctic Circumpolar Current, Bellingshausen Sea, Weddell Sea, and point source pollution from human activities including tourism, research, and fishing. Our results illustrate that point source pollution is more likely to serve as a source for observed plastics and may increase plastic load along the peninsula by an order of magnitude relative to plastics from non-point sources. Point source pollution also increased plastic loads around penguin colonies relative to non-point source pollution. We identified the penguin colonies at the greatest risk for high plastic loads and propose a stratified sampling and monitoring

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effort to determine the realistic plastic loads observed at these colonies and to build a better understanding of plastic distributions, concentrations, and origins within the Earth's final pristine environment.

POSTER #52

Direct and Indirect Contributions of the Cryosphere to Micronutrient Supply to the Open Surface Waters Around Antarctica

Professor Eileen Hofmann[1], Mike Dinniman[1], Pierre St-Laurent[2], Kevin Arrigo[3], Gert van Dijken[3]

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Previous studies showed that satellite-derived estimates of chlorophyll a in coastal polynyas over the Antarctic continental shelf are correlated with the basal melt rate of adjacent ice shelves. A 5-km resolution ocean/sea ice/ice shelf model of the Southern Ocean is used 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 source iron concentration for each tracer, and an idealized summer biological uptake. Iron from ice shelf melt provides about 6% of the total dissolved iron in surface waters. The contribution from deep sources of iron on the shelf (sediments and Circumpolar Deep Water) 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 confirm the previous suggestion 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. This dependence highlights the potential vulnerability of coastal Antarctic ecosystems to changes in ice shelf basal melt rates.

POSTER #53

Monitoring Adélie penguin populations: Indicators of change in the Ross Sea region

Dr Esme Robinson[1], Kerry Barton[2], Professor Jordy Hendrikx[1], Rebecca Macneil, Dr Fiona Shaunhun[3], Dr Dean Anderson[4]

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Adélie penguins (Pygoscelis adeliae) are a bio-indicator species, used by the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) to monitor the health and function of marine ecosystem processes. New Zealand has undertaken monitoring of Adélie penguin populations in the Ross Sea region since the early 1980s. Aerial reconnaissance and photography are used to determine the breeding locations of the birds, and to count the number of nests occupied during the early incubation period. Colonies on Ross Island are surveyed annually (Cape Crozier, Cape Bird and Cape Royds). Locations along the Northern Victoria Land Coast are surveyed at five yearly intervals. The census provides data against which future population levels can be compared, in order to monitor environmental change of the Ross Sea ecosystem, both natural and anthropogenic. The accumulated (and ongoing) survey information collected by this significant long-term research programme now provides a valuable resource, that contributes to management of the Southern Ocean Antarctic Toothfish fishery, and monitoring of the Ross Sea region Marine Protected Area, as well as contributing to the research goals of the Committee for Environmental Protection. This poster presents the latest Ross Island Adélie penguin population data, as well as data from selected Northern Victoria Land sites. Results highlight the value of long-term records of top predator abundance and distribution.

POSTER #54

An unprecedented season for sea ice: the view from the ocean

Natalie Robinson[1], Brett Grant[1], Ollie Twigge[1], Craig Stewart[1], Greg Leonard[2], Ken Ryan[3]

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The 2022 Antarctic sea ice growth season was unprecedented in the satellite era, including the lowest pan-Antarctic September extent on record. In McMurdo Sound the fast ice cover formed and re-formed several times until the end of August, when a stable cover was finally established – four months later than usual. This local effect was driven by a series of southerly storms that drove extreme activity of the McMurdo Sound polynya. As a result, new sea ice growth occurred throughout the winter, driving deep and persistent brine rejection. This offset in timing also affected recruitment of, and into, the sub-ice platelet layer (SIPL). This resulted in two highly differentiated SIPL regimes which were exploited for surface-based sampling in October and November. Here we present new ocean data from southern McMurdo Sound, captured throughout this unusual season with a novel seafloor-mounted mooring. Instead of the expected homogenising of the water column through the autumn months, significant spatial and temporal variability persisted through to the end of the winter months, to depths as great as 250 m below sea level.

POSTER #55

Observing Antarctic Bottom Water in the Southern Ocean

Dr Alessandro Silvano[1], Dr Denise Fernandez[2], Professor Craig Stevens[2], Professor Zhaomin Wang[3]

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Dense, cold waters formed on the Antarctic continental shelf descend along the Antarctic continental margin, where they mix with Southern Ocean waters to form Antarctic Bottom Water (AABW). AABW then spreads into the deepest parts of all major ocean basins, trapping heat and carbon away from the atmosphere for centuries. Despite its key role in regulating Earth's climate on long time scales, AABW remains poorly observed. This lack of observational data is mostly due to two factors. First, AABW originates on the Antarctic continental shelf where in situ measurements are limited and ocean observations by satellites are hampered by persistent sea ice cover and long periods of darkness in winter. Second, north of the Antarctic continental slope, AABW is found below about 2 km depth, where in situ observations are also scarce and satellites cannot provide direct measurements. Here we discuss future avenues for observing AABW, highlighting the role of new technologies and key areas to monitor. The potential development of a sustained and coordinated AABW observing system will be introduced.

POSTER #56

Recommendations to accelerate the development of a sustained and fully Integrated Polar Observing System: an EU-PolarNet 2 White Paper

Dr Gael Lymer, **Dr Renuka Badhe**, Pjotr Elshout, Dr Jan René Larsen, Dr Hannele Savela, Dr Serge Scory, Vanessa Spadetto, **Dr Anton Van De Putte**[1]

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The EU-PolarNet 2 (funded by the EU-H2020) aims to co-develop and advance the European polar research actions, and to give evidence-based advice to policy making processes. It is one of the world's largest consortia of polar research expertise and infrastructures, composed of 25 partners representing all European Member States and Associated Countries which have well-established Polar Programmes. By involving all relevant stake- and right-holders, EU-PolarNet 2 will support the development of transdisciplinary and transnational Polar research actions of high societal relevance. To ensure that activities of such importance are sustained in the future, the project will implement a permanent European Polar Coordination Office (EPCO) to be hosted within the secretariat of the European Polar Board.

An important objective of the EU-PolarNet 2 project is to facilitate better alignment of observing system efforts from both poles, and to create actionable policy-level recommendations to accelerate the development of an Integrated Polar Observing System (IPOS). IPOS would provide a coordinated system for continuous, standardized data and societally relevant information on the state of the polar regions that would result in an improved comprehensive view on polar regions.

In order to concretely implement IPOS, EU-PolarNet 2 is collecting recommendations from the polar research, observing and data communities, including both Arctic and Antarctic organizations, projects, institutions and stakeholders working with observing systems at various domains and scales. These recommendations will feed into a white paper to be published and distributed to a wide range of policymakers and funding bodies. A workshop held in June 2022 has resulted in a first document with fundamental recommendations for the white paper (D6.4_Minutes-of-a-workshop-with-coordinators-of-european-polar-observing-systems). Now that the white paper process has started, additional recommendations and feedback are being collected via direct meetings with all partners willing to participate and have their voices heard in co-designing the white paper.

With this poster, our aim is to raise awareness and inform about the EU-PolarNet 2 white paper. We will present the draft structure of the white paper, based on the recommendations collected from the polar communities. We will also introduce short- and long-term recommendations articulated around the fundamental pillars identified to ensure the implementation of IPOS, namely: Data, Infrastructure, Funding, Governance and Structure, & Collaborations, Research and Stakeholders. Finally, we will provide information on the white paper process and ways to contribute, so that partners will be able to provide their feedback on the white paper, before it is delivered to the European Commission in Spring 2024.

POSTER #57

Helicopter-based ice-covered ocean observations capture broad ocean heat intrusions towards the Totten Ice Shelf

Dr Yoshihiro Nakayama[1], **Dr Pat Wongpan**[1,2,3], Dr Jamin Greenbaum[4], Dr Kaihe Yamazaki[1,5], Tomohide Noguchi[6], Daisuke Simizu[5], Dr Haruhiko Kashiwase[7], Dr Donald Blankenship[8], Dr Takeshi Tamura[5,9], Dr Shigeru Aoki[1]

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Rapid climate change affects the physical, chemical, and biological aspects of ice-covered oceans. The recent discovery of warm ocean water near the Totten Ice Shelf (TIS) has increased attention to the Sabrina Coast in East Antarctica. To understand the pathways and mechanisms of warm water inflow, ocean observations for entire continental shelf regions

are necessary. This has historically not been possible due to intense sea ice and icebergs

in the region. We report the result of 6-day helicopter-based observations using AXCTD (Airborne eXpendable Conductivity, Temperature, and Depth) and AXBT (Airborne Bathy-Thermograph) including the deployment through landfast sea ice (fast ice) cracks (~15-540 m). The observations conducted during the 61st Japanese Antarctic Research Expedition (JARE61) revealed warm ocean water (0.5-1°C) occupying a large previously unsampled area of the Sabrina Coast (116.5°E-120°E) below 550-600 m. Along the TIS front, we observe modified Circumpolar Deep Water (mCDW) well above freezing (~-0.7°C), consistent with previous work. We identify glacial meltwater outflow from the TIS cavity west of 116°E. No signs of mCDW intrusions towards the Moscow University Ice Shelf cavity are observed;

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however, those observations were limited to only two shallow (~330 m) profiles. During our flight observations, we attempted to conduct four east-west hydrographic sections and were able to complete all these sections by finding small sea ice cracks although most of the area was almost 100% covered by sea ice. At the time when helicopter-based measurements were conducted, existing observations were limited to the area close to the coast and inside the Dalton Polynya; the helicopter-based measurements discussed here allow us to obtain large-scale hydrographic features of the continental shelf region, despite intense sea ice and iceberg conditions at the time. We also highlight the advantages of helicopter-based observations for accessibility, speed, maneuverability, and cost-efficiency. The combination of ship- and helicopter-based observations using the JARE61 approach will increase the potential of future polar oceanographic observations.

We would like to thank all attendees for being part of this inaugural event.

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