SOUTHERN OCEAN OBSERVING SYSTEM

Report Series

The Weddell Sea and Dronning Maud Land (WSDML) Regional Working Group Virtual Science Workshop, 14 - 16 June 2022

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The Weddell Sea and Dronning Maud Land (WSDML) Regional Working Group Virtual Science Workshop

14–16 June 2022

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1) Introduction

The Weddell Sea Dronning Maud Land (WSDML) Regional Working Group (RWG) science workshop was carried out virtually, following the successful format of the previous 2020 workshop. The workshop was held during three days in three-hour time blocks. Approximately two hours each day were focused on science presentations organized by discipline (Glaciology, Sea Ice, Oceanography, Biogeochemistry, Ecosystem), while the remaining hour was reserved for RWG-related and networking discussions, including opportunities to share projects and field plans, SOOS data management, and ideas to improve the interaction and networking capabilities within the WSDML working group. The 42 registered participants had the option to apply for full-length (15 min) or lightning talks (5 min), as an opportunity to present preliminary results as a replacement for a poster session. The organizing committee consisted of the two RWG co-chairs and members of the leadership group, who equally contributed to session chairing and discussion leading.

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2) Scientific Sessions

Day 1: 14 June 2022 (Glaciology, Sea Ice, Biogeochemistry I)

The first scientific session Glaciology (chaired by Stefanie Arndt), comprised of two talks with a focus on Dronning Maud Land. Jane Lund Andersen (Aarhus University) presented on the long-term ice cover and erosion histories in the East Antarctic. Olaf Eisen (AWI) focused on three decades of accumulation records monitored at Neumayer station. The following Sea Ice-session (chaired by Markus Janout) was opened by Ethan Campbell (University of Washington), who introduced a methodology to reconstruct Antarctic Sea ice growth and snow accumulation, based on autonomous float data and sea ice parcel tracking. Stefanie Arndt (AWI) then discussed sea ice growth and snow properties in two different Weddell Sea regions, based on a number of recent icebreaker expeditions. Her findings underlined the need to distinguish between seasonal and perennial sea ice regarding snow properties and processes. Next, Louise Biddle (University of Gothenburg) presented on novel observations from ice mass balance buoys deployed in the marginal ice zone in the eastern Weddell Sea, which she used to characterize ice drift and melt related to oceanic and atmospheric heat fluxes. The final talk of this session by Stina Wahlgren (University of Gothenburg) presented the first observations from SWIFT buoys of surface waves in the marginal ice zone in the Weddell Sea.

The first workshop day was concluded by the first of two Biogeochemistry-sessions (chaired by Sandy Thomalla). Megan Lenss (Norwegian Polar Institute) shared observations from an early bloom onset in the King Haakon VII Sea, which was related to glacial and sea ice meltwater input. Following Megan, Nuria Gonzalez (University of Barcelona) presented modeling results on the organic matter degradation on the Weddell Sea continental shelf. Finally, Raquel Flinn (University of Cape Town) investigated the role of nanoplankton and iron limitation on carbon export in the Southern Ocean.

Day 2: 15 June 2022 (Oceanography)

The second day was dominated by Oceanography-science presentations (chaired by Louise Biddle). Krissy Reeve (AWI) started the session by presenting her Argo float-based analyses on the Weddell Gyre's heat budget, where she emphasized the role of turbulent diffusion in redistributing heat. Her talk was followed by a series of presentations with a focus on Filchner Trough in the southeast Weddell Sea. Markus Janout (AWI) presented on recent variability in the Ice Shelf Water circulation in Filchner Trough based on new mooring records recovered in 2021. Nadine Steiger (Sorbonne University) presented new time series observations from the modified Warm Deep Water inflow in Filchner Trough, followed by Elin Darelius (University of Bergen), who discussed the dynamics and variability of warm ocean waters at the Filchner continental slope. Xianxian Han (Xiamen University, China) presented idealized modeling results on the role of topographic Rossby waves for the descent of dense waters at the Weddell Sea continental slope. Xin Wang (University of Delaware) discussed the importance of the Weddell Sea in regulating the water exchange along the West Antarctic Peninsula. Mike Meredith (British Antarctic Survey) provided a pre-recorded presentation from his stable oxygen isotope-based study, that highlighted the recent freshwater variability in the Scotia Sea and the northern Weddell Sea. The session was concluded by Ria Oelerich (University of East Anglia), who talked about the barrier/blender properties of the Southern Boundary of the Antarctic Circumpolar Current and interactions with eddies.

Day 3: 16 June 2022 (Biogeochemistry II, Ecosystem)

The third workshop day commenced with the Biogeochemistry II-session (chaired by Ethan Campbell). Andreas Rogge (AWI) presented recent findings from the Filchner Trough and highlighted the impact of dense water transport on particle dynamics and carbon sequestration. Isabelle Giddy (University of Gothenburg, University of Cape Town) then discussed how sea ice can impact the variability of carbon export in the Weddell Sea. Elise Droste (University of East Anglia) presented findings from a study relating tides and sea ice to carbonate chemistry in a coastal polynya near the Ekström Ice Shelf. Joshua Mirkin (University of Cape Town) presented study in which he investigated nitrogen isotopic ratios to quantify carbon export in front of the Larsen C Ice Shelf. Mhlangabezi Mdutyana (University of Cape Town) then concluded the session by discussing his study of nitrite thresholds and oxidation in the Southern Ocean based on winter kinetics experiments.

The final scientific session included three Ecosystem-presentations (chaired by Stefanie Arndt). The first talk by Marcela Libertelli (Argentine Antarctic Institute) shared her monitoring efforts of Emperor penguin colonies in the northern Weddell Sea. Then, Tomas Marina (Centro Austral de Investigaciones Cientifica, Argentina) presented on his new insights into the Weddell Sea ecosystem using a network approach. The final talk of the workshop was held by Clara Douglas (National Oceanography Center, UK) about her work on the effects of sea ice on primary production in the Weddell Gyre.

3) SOOS and RWG-related sessions and discussions

The outside-of-science-sessions were designed to promote and discuss SOOS and the WSDML-RWG aims, tools, and opportunities, and further to share ideas on networking and information exchange. Following the welcome and introduction by the organizers, the workshop was started with a presentation on SOOS and the data and project sharing capabilities Due South/Polardex by the SOOS executive officer Alyce Hancock. The presentation served as a motivation to make use of the SOOS options, which are designed to strengthen the community through enhanced information and data sharing activities.

The new SOOS Science and Implementation Plan (SIP) was recently accepted and now serves as a guide on the important challenges and SOOS' role in addressing these. RWGs play an important role in strengthening the community and generating data through the integration of regional projects and programs. The goal of the "Regional Working Group: Internal discussions and aims"-session was to discuss the different WSDML-subregions with respect to the challenges outlined in the SIP, and to finally rate each subregion's importance with respect to the scientific challenges. Attendants contributed actively to the discussion, although due to a more general discussion on research and data subjects in the WSDML region, the rating was not finalized in the short time available. This task requires a streamlined conversation in a small group with sufficient time. It was highlighted that rating the importance of various challenges is a highly subjective and difficult task. Some suggestions included sending out a "Google Poll" type survey to all attendees to get a statistical representation, as each individual will be biased towards the challenges they have more expertise or knowledge of.

The communication within the RWG is currently limited to official email distributions via the Mailchimp-mailing list as well as through SOOS-newsletters. A lower-level interaction tool does not yet exist. Ethan Campbell therefore presented on the idea to set up a Slack-channel for RWG members, in order to exchange unofficial information, papers and opportunities, which may be particularly beneficial for networking and career building of young researchers.

The final workshop hour was used to exchange upcoming project and expedition plans. German participants reported that there is no scheduled Polarstern expedition into the Weddell Sea for the upcoming years. However, they plan several studies on landfast sea ice close to the German overwintering base Neumayer Station III (Atka Bay). Norwegian participants informed on upcoming research plans near the Fimbul Ice Shelf, as part of a large Norwegian Infrastructure project. The upcoming EU-funded project OCEAN:ICE with an Antarctic focus is due to start at the end of 2022. The project follows a circumpolar approach using models and observations, and will also contribute to data generation in the WSDML region. The Swedish participants highlighted a push from the national community to gather support from the national Polar agency and invited any interested parties to contact them for potential future collaborations.

Finally, we held a discussion on potential review paper plans to be led within the RWG. The participants held a lively conversation and discussed different subjects and regions including potential topics focusing on (for instance) Maud Rise, Filchner Trough or on fluxes in the Weddell Sea.

4) Concluding remarks

The workshop was once again an important opportunity for interdisciplinary and international exchange within the WSDML working group. Both the scientific lectures and the additional blocks, such as international projects/expeditions, were used to generate lively discussions online and beyond. This feedback encourages us to continue such a workshop on a 2-year cycle.

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5) Attachements

i) Workshop schedule

ii) Abstracts

Regional Working Group Workshop "Weddell Sea Dronning Maud Land"

June 14 - 16, 2022

online at: https://awi.webex.com/awi/j.php?MTID=m228a5c1bd013cd806b807748eb6f1a0d

Time is CET (UTC+2hrs)

DAY 1: Tuesday, June 14

13:00 – 13:15	Welcome and workshop introduction *Leadership team*
Outside the pure science-box	
13:15 – 14:00	SOOS/ Due South/Polardex *Alyce Hancock (SOOS Office)*
Glaciology	Chair: Stefanie Arndt
14:00 – 14:05	Long-term ice cover and erosion histories in Dronning Maud Land, East Antarctica *Jane Lund Andersen (Aarhus University)*
14:05 – 14:10	30 years of accumulation at Neumayer station *Olaf Eisen (Alfred Wegener Institute)*
14:10 – 14:15	Break
Sea Ice	Chair: Markus Janout
14:15 – 14:20	Towards Lagrangian reconstructions of Antarctic sea ice growth and snow accumulation: a Weddell Sea case study *Ethan Campbell (University of Washington)*
14:20 – 14:35	Sensitivity of sea ice growth to snow properties in opposing regions of the Weddell Sea in late summer *Stefanie Arndt (Alfred Wegener Institute)*
14:35 – 14:50	Sea ice drift, melt and heat fluxes revealed by two novel deployments of Seasonal Ice Mass Balance buoys in winter and spring in the eastern Weddell Sea *Louise Biddle (University of Gothenburg)*
14:50 – 15:05	In-situ observations of surface waves in the Antarctic marginal ice zone *Stina Wahlgren (University of Gothenburg)*
15:05 – 15:15	Break

Bio-Geo-Chemistry I Chair: Sandy Thomalla

15:15 – 15:30 Early bloom onset related to glacial and sea ice meltwater input in the King Haakon VII Sea, Southern Ocean

Megan Lenss (Norwegian Polar Institute)

15:30 – 15:45 Modelling the organic matter degradation at the continental shelf of the Weddell Sea

Núria González (Universitat de Barcelona)

15:45 – 16:00 Nanoplankton: vectors of carbon export across the springtime Southern Ocean

Raquel Flynn (University of Cape Town)

DAY 2: Wednesday, June 15

Oceanography	Chair: Louise Biddle
13:00 – 13:05	The role of turbulent diffusion in redistributing heat in the Weddell Gyre *Krissy Reeve (Alfred Wegener Institute)*
13:05 – 13:10	Ice Shelf Water Circulation in Filchner Trough on the southeast Weddell Sea shelf *Markus Janout (Alfred Wegener Institute)*
13:10 – 13:15	Observing a key inflow region to the southern Weddell Sea continental shelf *Nadine Steiger (Sorbonne Université)*
13:15 – 13:30	Warm water on the continental slope north of the Filchner Trough *Elin Darelius (Universitetet i Bergen)*
13:30 – 13:45	Topographic Rossby Wave accelerate the descent of dense overflows *Xianxian Han (Xiamen University)*
13:45 – 14:00	Weddell Sea Influence on the Water Exchange along the West Antarctic Peninsula Continental Shelf *Wang Xin (University of Delaware)*
14:00 – 14:10	Break
14:10 – 14:25	Freshwater variability in the surface Scotia Sea and northern Weddell Sea, 2016-2021: insights from stable oxygen isotopes *Michael Meredith (British Antarctic Survey)*
14:25 – 14:40	Stirring across the Antarctic Circumpolar Current‘s Southern Boundary at the Greenwich Meridian, Weddell Sea *Ria Oelerich (University of East Anglia)*
14:40 – 14:50	Break
Outside the pure science-box	
14:50 – 15:45	Regional Working Group: Internal discussions and aims *Chair: Markus Janout*
15:45 – 16:00	Slack as quick communication tool within the WSDML group *Chair: Ethan Campbell*

DAY 3: Thursday, June 16

Bio-Geo-Chemistry II Chair: Ethan Campbell

13:00 – 13:15	Impact of dense water transport on particle dynamics and carbon flux in the Filchner Trough area *Andreas Rogge (Alfred Wegener Institute)*
13:15 – 13:30	Sea ice impacts on interannual variability of carbon export in the Weddell Sea *Isabelle Giddy (SOCCO-CSIR, Gothenburg University & University of Cape Town)*
13:30 – 13:35	The role of tides and sea ice on the carbonate chemistry in a coastal polynya in the south-eastern Weddell Sea *Elise Droste (University of East Anglia)*
13:35 – 13:40	A nitrogen isotope view of nutrient supply and productivity adjacent to Larsen C Ice Shelf in the Western Weddell Sea, Antarctica *Joshua Mirkin (University of Cape Town)*
13:40 – 13:55	An apparent threshold nitrite concentration requirement for nitrite ox. in the Southern Ocean: Evidence from winter kinetics experiments *Mhlangabezi Mdutyana (University of Cape Town)*
13:55 – 14:05	Break

Ecosystem Chair: Stefanie Arndt

14:05 – 14:20	Monitoring of two emperor colonies during several breeding seasons in the Weddell Sea, Antarctica *Marcela Libertelli (Argentine Antarctic Institute)*
14:20 – 14:35	New insights into the Weddell Sea Ecosystem applying a network approach *Tomas Ignacio Marina (Centro Austral de Investigaciones Cientificas)*
14:35 – 14:40	Sea Ice and Primary Production in the Weddell Gyre *Clara Douglas (NOC Southampton)*
14:40 – 14:50	Break

Outside the pure science-box

14:50 – 15:20	Introduction of international projects and upcoming expeditions interesting for the WSDML group *Chair: Stefanie Arndt*
15:20 – 15:50	Discussion on potential review paper within the WSDML group *Chair: Ethan Campbell / Markus Janout*
15:50 – 16:00	Wrap-up of the workshop

Abstract compilation

Glaciology

Long-term ice cover and erosion histories in Dronning Maud Land, East Antarctica

Jane Lund Andersen (Aarhus University), J.C. Newall, O. Fredin, N. F. Glasser, N.A. Lifton, A.J. Koester, F.M. Stuart, V.K. Pedersen, D. L. Egholm, J.M. Harbor, A.P. Stroeven

The impact of late Cenozoic climatic changes on the configuration of the East Antarctic Ice Sheet (EAIS) is uncertain. While the EAIS margins likely extended close to the shelf edge along most of the perimeter during phases of Pleistocene global cooling, the interior ice sheet thinned due to moisture starvation from a cooler and more distal Southern Ocean. Yet, the spatial pattern of relative thinning and thickening remains sparsely constrained, impairing the reconstruction of past global sea level budgets. Here we apply inverse modelling of cosmogenic 36Cl, 26Al, 10Be, and 21Ne in bedrock to quantify the long-term erosion and ice cover histories of mountains protruding the EAIS in Heimefrontfjella and fringing the Jutulstraumen Ice Stream in western Dronning Maud Land. Our findings demonstrate that the EAIS only briefly experienced episodes of thicker-than-present ice in Heimefrontfjella, while the EAIS covered sample sites along Jutulstraumen for up to 90% of the time as it thickened ~300 m above the present-day ice sheet, during the last 1 Myr. For both regions, samples collected above c. 1.7 km a.s.l. have resided within 1 m of the present-day surface since the Late Miocene or Pliocene (>3.2-4.5 Ma), with low erosion (<20 cm) and limited ice cover (<20 %) during the last 1 Myr.

30 years of accumulation at Neumayer station

Olaf Eisen (Alfred Wegener Institute)

Surface mass balance is one of the key glaciological variables to determine the present state and future evolution of an ice mass under global climate heating. In particular in Antarctica, surface mass balance is still insufficiently know. Given the size of the ice sheet direct observations or reconstructed values from firn and ice cores are sparse. Indirect satellite remote sensing methods either provide only an integral view of the mass balance (e.g. from gravity missions like GRACE), observe the total change of surface elevation or, like passive microwave observations, come along with considerable uncertainties.

With the end of the year 2021 a 30-year record of surface snow accumulation at the German Neumayer overwintering stations has been completed. The data were recorded at approximately fortnightly intervals at the stake farm of the “Pegelfeld Süd“. This provides us now with a time series over a standard climate period which can be used investigate the interaction of surface accumulation with other environmental properties like temperature, wind, sea ice cover and alike. Moreover, it can be used validate other products, e.g. from remote sensing or regional climate modelling. The surface accumulation data are complemented by less regular density measurements as well as a second stake farm established in 2009 at the Neumayer station III. We will present first and preliminary result of the annual evolution as well as seasonal characteristics of surface accumulation.

Sea Ice

Towards Lagrangian reconstructions of Antarctic sea ice growth and snow accumulation: a Weddell Sea case study

Ethan Campbell (University of Washington), S. Riser

Here we present progress towards two distinct, but related, efforts to reconstruct Antarctic-wide sea ice thickness and snow depth on sea ice. We estimate sea ice formation and melt rates from local upper-ocean salinity budgets along the drift trajectories of under-ice Argo profiling floats. Closing these salinity budgets, however, requires knowledge of freshwater fluxes from snow. To obtain these fluxes, we estimate snow mass accumulation and melt based on ERA5 reanalysis snowfall along observed sea ice motion trajectories. We discuss the potential importance of loss processes such as sublimation and lead trapping of blowing snow. Preliminary results from the Weddell Sea are presented for comparison with existing measurements and remote sensing products.

Sensitivity of sea ice growth to snow properties in opposing regions of the Weddell Sea in late summer

Stefanie Arndt (Alfred Wegener Institute)

The sensitivity of sea ice to the contrasting seasonal and perennial snow properties in the southeastern and northwestern Weddell Sea is not yet considered in sea ice model and satellite remote sensing applications. However, the analysis of physical snowpack properties in late summer in recent years reveal a high fraction of melt-freeze forms resulting in significant higher snow densities in the northwestern than in the eastern Weddell Sea. The resulting lower thermal conductivity of the snowpack, which is only half of what has been previously assumed in models in the eastern Weddell Sea, reduces the sea ice bottom growth by 18 cm. In the northwest, however, the potentially formed snow ice thickness of 12 cm at the snow/ice interface contributes to an additional 2 cm of thermodynamic ice growth at the bottom. This emphasizes the enormous impact of unappreciated regional differences in snowpack properties on the thermodynamic ice growth.

Sea ice drift, melt and heat fluxes revealed by two novel deployments of Seasonal Ice Mass Balance buoys in winter and spring in the eastern Weddell Sea

Louise Biddle (University of Gothenburg), S. Swart

The sea ice extent in the Weddell Sea-Dronning Maud Land region varies from the edge of the continental shelf in summer to 55°S in winter, covering a huge expanse of ocean as it grows and melts seasonally. The presence of sea ice can change momentum, freshwater and heat fluxes, affecting upper ocean mixing, biological productivity and carbon export. Knowledge of the primary forcing behind sea ice growth/melt and the transfer of heat across the ice-ocean boundary is critical to understand in this undersampled region, where observations are lacking to validate satellite sea ice thickness measurements and precipitation estimates from reanalysis products. Here, we present results from the first Southern Ocean Marginal Ice Zone deployments of Seasonal Ice Mass Balance buoys (SIMBs) in winter and spring 2019. They show five times greater snowfall during the spring period than ERA-5 reanalysis estimates (0.97 m snowfall over 27 days), and a positive freeboard throughout the study

period on both deployments. The fate of the sea ice showed distinct seasonal differences, with winter most affected by transient storm events, and spring impacted by sustained oceanic and atmospheric heat fluxes resulting in a sea ice thinning of 0.23 m (38% loss) in 4 days. These first-of-their-kind observations show that to improve understanding of the linkages between sea ice and air-sea fluxes we need better characterisation of the Southern Ocean Marginal Ice Zone throughout the annual cycle.

In-situ observations of surface waves in the Antarctic marginal ice zone

Stina Wahlgren (University of Gothenburg), S. Swart, L. Biddle, J. Thomson

Antarctic sea ice has an important impact on the global climate, affecting albedo, global circulation and heat- and gas exchange between the ocean and the atmosphere. Wave energy propagating into the sea ice can affect the quality and extent of the sea ice, and is therefore an important factor for understanding and predicting changes in the ice cover. Wave-sea ice interactions have gained renewed attention in recent years, but much is still unknown. Sea ice is notoriously hard to model and in-situ observations of wave activity in the Antarctic marginal ice zone are scarce, due to the extreme conditions of the region.

We here study in-situ data from two drifting Surface Wave Instrument Float with Tracking (SWIFT) buoys deployed in the Weddell Sea for two days in the Antarctic winter and two weeks in the Antarctic spring in 2019. The buoy location ranges from open water to more than 200 km into the sea ice. We estimate the attenuation of swell with wave periods 10-20s, and find an exponential decay consistent with other field observations in the Arctic and Antarctic marginal ice zones. The in-situ data also shows a change in dominant wave direction that appears to be caused by refraction, where wave direction tends to be more perpendicular to the ice edge farther into the sea ice.

These observations can help shed further light on the influence of sea ice on waves propagating into the marginal ice zone, which is important for the development of coupled wave-sea ice models.

Oceanography

The role of turbulent diffusion in redistributing heat in the Weddell Gyre

Krissy Reeve (Alfred Wegener Institute), T. Kanzow, O. Boebel, V. Strass, M. Hoppema, W. Geibert

Float observations were used to diagnose key terms in the heat conservation equation for a 1000 m thick layer encompassing the Warm Deep Water, the primary heat source water mass of the Weddell Gyre, for the period 2002-2016. While heat is advected into the southern limb of the gyre from the east, horizontal turbulent diffusion plays an important role in redistributing that heat in the meridional direction, i.e. towards the centre where upwelling occurs. While horizontal circulation and inferred upwelling rates are stronger in the eastern sub-gyre than the western sub-gyre, baroclinic shear due to the influence of topography at the open northeastern boundary implies the importance of mesoscale dynamical processes east of the Prime Meridian. The results suggest that in order to comprehend the role of upwelling within the Weddell Sea in a larger climate context, further observing of the eastern Weddell Sea region is required.

Ice Shelf Water Circulation in Filchner Trough on the southeast Weddell Sea shelf

Markus Janout (Alfred Wegener Institute)

The Filchner Trough in the southern Weddell Sea receives outflow of Ice Shelf Water (ISW) from underneath Filchner-Ronne Ice Shelf (FRIS) as well as inflow of modified Warm Deep Water (mWDW) from the shelf break. ISW is a key part of the dense water masses that flow of the continental slope into the deep Weddell Sea as precursors of Antarctic Bottom Water (AABW), and further prevent a large-scale inflow of mWDW toward the ice shelf. Recent findings defined two modes of circulation (Berkner- and Ronne-modes) in Filchner Trough, where the former describes a locally-forced circulation, while the latter is characterized by enhanced outflow of cold ISW from Filchner Ice Shelf likely forced by strong sea ice formation in the southwest Weddell Sea. Observations from underneath as well as in front of FRIS showed a shift from the Berkner- to Ronne-mode in 2017, which subsequently dominated the Filchner Trough hydrography before shifting back to a Berkner-mode in 2020. In this short presentation, I will provide a quick update on results from the recentmost expedition to the region in 2021 and briefly discuss the circulation in Filchner Trough.

Observing a key inflow region to the southern Weddell Sea continental shelf

Nadine Steiger (Sorbonne Université), J.-B. Sallée

The Filchner Trough on the continental shelf in the southern Weddell Sea serves as a conduit for warm water towards the Filchner Ice Shelf. The warm water originates from the open ocean and has to cross the shallow sill close to the shelf break before being steered southward along the eastern slope of the Filchner Trough. Beneath the layer of warm water, northward flowing cold and dense Ice Shelf Water at the bottom of the trough has been observed to overflow the sill, contributing to the formation of Antarctic Bottom Water. We present mooring records from 2017 to 2021 that provide observations of the interplay between the warm inflow and the cold outflow over the Filchner Trough sill. The observations of the inflow over the sill region are complemented by observations from Argo

floats and another mooring placed further east over the shallower continental shelf, where a smaller trough provides an alternative route for warm water to be transported southward. The four year long observations provide a better understanding of the processes that influence the variability in temperatures and circulation of the warm water, and possible changes in the heat flux towards the ice shelf.

Warm water on the continental slope north of the Filchner Trough

Elin Darelius (Universitetet i Bergen), M. Janout, H. Hellmer, J.-B Sallee, S. Østerhus, K. Daae, V. Dundas, K. Nicholls

The factors and processes governing the inflow of Warm Deep Water (WDW) onto the continental shelf in the southern Weddell Sea and towards the ice shelf cavities are poorly understood. Here we present historical and new observations from the slope region to a) provide evidence that topographically steered, downslope flow of dense water is associated by upslope and onshelf flow of WDW (as suggested by Morrison et al, 2020, based on numerical simulations) and b) that WDW temperatures above the upper part of the slope in 2021 were 0.1C higher than what has previously been observed.

Topographic Rossby Wave accelerate the descent of dense overflows

Xianxian Han (Xiamen University) , D. Chen, A. Stewart

The global supply of Antarctic Bottom Water (AABW) is sourced from a handful of dense overflows. Observations from the Weddell Sea indicate that the overflow there exhibits prominent oscillations accompanied by dense eddies, yet the genesis of these oscillations and their role in mediating AABW export remain poorly understood. Here we use idealized model simulations to investigate the dynamics of these oscillations. It is shown that the dominant oscillations result from the formation of Topographic Rossby Waves (TRWs). A key finding is that the TRWs can feedback onto the dense overflow, producing subsurface eddies of the same frequency and accelerating the descent of the dense overflows. A series of sensitivity experiments reveal that these behaviors depend strongly on the local environment, with steep slopes or strong westward along-slope flows suppressing the formation of TRWs and dense eddies. These results explain the varying prevalence of different oscillatory phenomena observed across different dense overflow regimes.

Weddell Sea Influence on the Water Exchange along the West Antarctic Peninsula Continental Shelf

Wang Xin (University of Delaware), X. Wang, C. Moffat, M.I S. Dinniman, J. M. Klinck, D. Sutherland, B. Aguiar-González

The West Antarctic Peninsula (WAP) is characterized by strong thermal gradients caused by the competing influences of the warm Bellingshausen Sea to the south and the Weddell Sea Water in Bransfield Strait to the north. The potential of these gradients for modulating the patterns of glacier retreat and marine productivity motivates a comprehensive understanding of the dynamics and variability of water connectivity between the different water masses along the WAP. Model simulations reveal a novel seasonal exchange process between the cWAP and Bransfield Strait, with a net influx of warm modified Circumpolar Deep Water (mCDW) towards Bransfield Strait in summer that reverses in winter with the shelf-wide

flooding of Weddell-sourced water to the northern cWAP. The intensity of this winter flooding is modulated by the intensity of winds over Bransfield Strait, which in turn vary on interannual scales with the Southern Annular Mode (SAM). Negative SAM results in weaker upwelling or downwelling-favorable winds, which favors the Weddell-sourced water flooding the cWAP shelf, leading to an area-averaged temperature decrease of 0.5°C of northern cWAP. This study shows that along-shore exchange between the Weddell-sourced water and mCDW is an important yet missing mechanism of current conceptual models of the property budgets along the WAP.

Freshwater variability in the surface Scotia Sea and northern Weddell Sea, 2016-2021: insights from stable oxygen isotopes

Michael Meredith (British Antarctic Survey), A. Haumann, E. P. Abrahamsen, M. Leng, C.I Arrowsmith, M. Barham, Y. Firing, J. A. Brearley, A. Meijers

The time-varying freshwater budget of the Weddell and Scotia seas is a critical factor that impacts stratification, circulation, convection and the exchange of heat, carbon and other properties between the atmosphere and ocean. Numerous factors govern the freshwater budget, including sea ice production and melt, ice sheet discharge, iceberg melt and precipitation. Here we use a time series of stable isotopes of oxygen in seawater during 2016-2021 to deconvolve the influence of these sources and their impacts. We find that the strong sea ice retreat following the record maximum in 2015 had a pronounced impact on the surface ocean salinity, with a lagged response reflecting advective timescales and the accumulation of melt anomalies. Superposed, the passage of giant iceberg A68 through the eastern Scotia Sea in 2021 generated strong glacial melt inputs locally, with up to 2m excess meteoric freshwater accumulated in the upper ocean. These results are discussed in the context of known and projected changes in freshwater sources, including other icebergs that transition through the region.

Stirring across the Antarctic Circumpolar Current‘s Southern Boundary at the Greenwich Meridian, Weddell Sea

Ria Oelerich (University of East Anglia), K. J. Heywood, G. M. Damerell, S. Swart, M. du Plessis, L. Biddle

The southern boundary (SB) of the Antarctic Circumpolar Current (ACC) describes the closest connection of warm ACC waters to colder waters within the marginal seas of Antarctica. It is well known that eddies cross the fronts of the ACC and are advected downstream, but how does an eddy interact with the SB of the ACC? How does it impact the frontal structure, the intensity of the frontal jet and mixing across the SB? These are questions that we aim to address. As part of the ROAM-MIZ project, ocean glider observations at the Greenwich Meridian (GM) between 54-57 °S from October 2019 to February 2020 provide a unique data set of 5 highly resolved hydrographic transects that cross the SB repeatedly. Water mass properties, maps from satellite altimetry (AVISO) data and dive average currents are used to identify the location, properties and rotational direction of eddies crossing the GM. We demonstrate that a cyclonic eddy crossing the GM impacts the SB’s frontal structure and intensity of the frontal jet. Mixing length scales (MLS, the length at which a water parcel can move before mixing laterally) present near zero values across the frontal jet while the

eddy is crossing and values near 25 km after the eddy has crossed the GM. The MLS indicate increased water parcel exchange between ACC waters and waters further south after the eddy has crossed the GM, which further implies that 'barrier' properties of the SB are reduced.

Bio-Geo-Chemistry

Early bloom onset related to glacial and sea ice meltwater input in the King Haakon VII Sea, Southern Ocean

Megan Lenss (Norwegian Polar Institute), S. Moreau, K. Cambpell, T. Hattermann, J. Lauber

The triggers of phytoplankton blooms in the Southern Ocean remain poorly explained in scientific literature. This study seeks to explain how sea ice melt is related to phytoplankton bloom onset in the King Haakon VII Sea sector of the Weddell Gyre. We present biological and biogeochemical data along a meridional transect (from the coastal polynyas to the northern edge of the sea ice) that suggests bloom onset occurs prior to complete sea ice retreat and may be related to light limitation relief, iron of sea ice origin as well algal seeding. Bloom onset prior to complete sea ice melt is likely related to changes in the light regime. As sea ice thins due to melting and the dynamic breakup of ice floes, increased light is introduced into the water column allowing for primary production to initiate. Additionally, the melting sea ice releases algal cells which may act as an inoculum to the water column. Following light, iron is the most limiting factor of primary production in the Southern Ocean, which sea ice melt also releases to the upper mixed layer. This study describes in detail the bloom initiation directly linked to the retreat and melting of sea ice in a poorly studied region of the Southern Ocean.

Modelling the organic matter degradation at the continental shelf of the Weddell Sea

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Modelling the organic matter degradation at the marine sediment column provide insights into understanding carbon dynamics at the seabed and assessing the marine biogeochemical cycle of this element. During summer, the massive continental shelf of the Weddell Sea receives thousands of tonnes of primary produced organic carbon; however, organic carbon content in the seabed sediment in this region does not reach higher values than elsewhere. Several factors interplay controlling the fate of organic carbon in the sediment column. On the one hand, abundant benthic communities thrive in this Antarctic region and may consume most of the organic carbon reaching the sea floor. Further, tidal currents also resuspend and distribute organic carbon along the shelf limiting its accumulation in the sediment column. On the other hand, the large longitudinal (approximately. 60º, from 0º to 60ºW) latitudinal gradients (approximately 12º, from 62ºS to 74ºS) in the Weddell Sea set conditions for various environmental conditions that may regulate the flux of carbon to the sea floor, for example, the western Weddell Sea undergoes severe multiannual ice cover, which in some years drastically limit primary production. In contrast, the eastern section regularly presents the typical Antarctic spring-summer primary production conditions. Here, we aim to find whether organic carbon degradation rates along the continental shelf of the Weddell Sea show subregional patterns and which environmental conditions control them.

Impact of dense water transport on particle dynamics and carbon flux in the Filchner Trough area

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Export of biologically fixed atmospheric CO2 into the deep ocean can act as a sink in the global carbon cycle due to long-term retention from the atmospheric carbon pool. Shelf systems are hotspots of carbon fixation but retention times here are thought to be short due to rapid recycling of the produced particulate organic carbon (POC) back into the atmosphere. The southern Weddell Sea shelf, however, is also a hotspot of dense water formation due to brine enrichment during sea ice formation. The outflow of dense water through Filchner Trough and its subduction into the deep Weddell Sea basin could drive a deep injection mechanism which would increase the retention time of large amounts of shelf-based POC drastically, but investigations on this process are missing. To resolve the impact of dense water transport on particle dynamics and to verify a potential deep carbon injection in the southern Weddell Sea, we performed transects of vertical profiles as well as lander deployments of optical particle counters and imaging systems during the COSMUS expedition in late summer 2021. Here we present preliminary results of this project and provide first lateral POC flux estimations by combining particle data with water mass properties and current velocities.

Nanoplankton: vectors of carbon export across the springtime Southern Ocean

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Southern Ocean (SO) phytoplankton growth is seasonally co-limited by light and iron (Fe) availability, the alleviation of which in spring should provide ideal conditions for elevated productivity and biological carbon (C) export. In spring 2019, we measured size-fractionated rates of net primary production, nitrogen (N; nitrate, ammonium, urea) and Fe (labile inorganic and siderophore-bound) uptake, and characterized the phytoplankton community across all major zones of the Atlantic SO. While picoplankton were numerically dominant, biomass was dominated by nanoplankton (mainly Chaetoceros chains; individual cell size ≤ 20 µm) with their relative contribution decreasing as the bloom progressed. Nitrate and labile inorganic Fe were the primary N and Fe sources consumed by the phytoplankton community regardless of latitude. The uptake rates generally increased southwards, and we observed luxury Fe and nitrate uptake in the Marginal Ice Zone. Nonetheless, C export potential was similar across all zones. This observation can be explained in part by the low Fe requirement of the nanophytoplankton (measured Fe:C uptake ratios ~2:1 µM/M). In contrast to the other zones, a shift towards flagellate and mixotrophic plankton dominance in the Polar Frontal Zone coincided with decreased Fe availability. This shift provides evidence that as the growing season progresses Fe availability will drive changes in the community composition, and will influence C export across the Atlantic SO.

The role of tides and sea ice on the carbonate chemistry in a coastal polynya in the south-eastern Weddell Sea

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Tides significantly affect the physical oceanography of polar coastlines, but their effect on the marine carbonate chemistry remains largely unexplored. We address this topic with two case studies in a coastal polynya in the south-eastern Weddell Sea, neighbouring the Ekström Ice Shelf. The case studies were conducted in January 2015 (PS89) and January 2019 (PS117), capturing semi-diurnal oscillations in the water column. These are pronounced in both physical and biogeochemical measurements for PS89. Advection of sea ice melt water from the north-east creates a fresher, warmer, more mixed water column during rising tide with lower dissolved inorganic carbon (DIC) and total alkalinity (TA) content. During ebbing tide, water from underneath the ice shelf decreases the polynya's temperature, increases the DIC and TA content, and creates a more stratified water column. The variability during the PS117 case study is much smaller. The contrasts in the variability between the two case studies underlines the complexity and highly dynamic nature of the system.

The variability in the polynya induced by the tides results in an air-sea CO2 flux that can range between a strong sink (-20 mmol m-2 day-1) and a small source (7 mmol m-2 day-1) on a semi-diurnal time scale. There is a potential risk of overestimating the polynya's flux by 98% or underestimating it by 108% (mistaking it for a source instead of a sink), if the extent of the variability induced by tides is not considered.

A nitrogen isotope view of nutrient supply and productivity adjacent to Larsen C Ice Shelf in the Western Weddell Sea, Antarctica

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The Southern Ocean accounts for >30% of the global ocean's sink of atmospheric CO2, removing it through the solubility and biological pumps. To investigate the biological pump near the understudied Larsen C Ice Shelf (LCIS) in the western Weddell Sea, we measured the nitrogen (N) isotope ratios of nitrate, ammonium, and particulate organic N for samples collected in summer 2019. From these data, we quantify carbon export potential by computing the f-ratio (i.e., the fraction of primary production that escapes recycling to sink into the ocean interior, thus removing CO2). We calculate a mean seasonally-integrated f-ratio of 0.8±0.1, far higher than estimates for the open Southern Ocean in summer (≤0.5), implying a high potential for carbon removal, likely due to the effect of ice melt on stratification and iron supply. Understanding biological N cycling is important not only for evaluating the present-day ocean carbon sink, but also for reconstructing carbon export in the past. The N isotopes of buried organic matter can be used as a proxy for past biological pump strength, provided the nitrate assimilation isotope effect (15ε) is well-constrained. We calculate a mean 15ε for the waters near LCIS of 4.75±0.83‰, slightly lower than previous estimates from the open Southern Ocean but within the reported uncertainty. Our study thus provides a new estimate of 15ε for the coastal Antarctic and shows that the present-day Weddell Sea adjacent to LCIS hosts a strong biological pump.

An apparent threshold nitrite concentration requirement for nitrite oxidation in the Southern Ocean: Evidence from winter kinetics experiments

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Across the winter Southern Ocean, nitrification dominates the mixed-layer nitrogen cycle, with some of the resultant nitrate fueling productivity in the subsequent growing season, potentially weakening the biological CO2 sink. To better understand the controls on Southern Ocean nitrification, we conducted nitrite (NO2-) oxidation kinetics experiments across the Indian sector in winter. While all experiments yielded a Michaelis-Menten relationship with NO2- concentration, the NO2- oxidation rates only increased once NO2- exceeded 115 to 245 nM, suggesting that NO2- oxidizing bacteria (NOB) require a “threshold” NO2- concentration to produce nitrate. The half-saturation constant ranged from 134 to 403 nM, indicating a fairly high affinity of Southern Ocean NOB for NO2-, in contrast to results from culture experiments. In the upper mixed layer, we measured ammonium oxidation rates that were two- to seven-fold higher than the coincident rates of NO2- oxidation, suggesting that NO2- oxidation is the rate-limiting step for nitrification in the winter Southern Ocean. The decoupling of ammonium and NO2- oxidation, combined with a possible NO2- concentration threshold for NOB oxidation, may explain the non-zero NO2- that persists throughout the Southern Ocean’s mixed layer in all seasons. We hypothesize that the threshold NO2- requirement of NOB indicates undersaturation of the heme-rich NO2- oxidoreductase enzyme, perhaps driven by the limited availability of iron in surface waters.

Ecosystem

Monitoring of two emperor colonies during several breeding seasons in the Weddell Sea, Antarctica

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Penguins are a dominant component of the avian biomass of the Antarctic continent and they can be highly sensitive to climate change and are important consumers at these high latitudes. Currently known that breeding colonies of emperor penguin are distributed between 64°S and 78°S from April to December. One of colonies of emperors penguins we are studying is situated on the south coast of Snow Hill Island, constituting the northernmost colony known in Antarctica. Most of breeding colonies occur on stable fast ice but four colonies on ice shelves have been observed and one of them is the other we are following, at Peninsula Jason. There is growing concern about the future of some Antarctic species in view of the changes observed in recent years with the extent and thickness of the sea ice pack related to global warming. The Emperor penguin depends on sea-ice pack as a breeding platform during the winter-spring months also it is the molting habitat and the foraging environment. Recent studies suggest that emperor penguin populations will decline in future decades due to climate change. We conducted aerial census of adult individuals for many consecutive years for the same period of the breeding chronology. The assessment of this penguin population located in the Weddell Sea will contribute to the estimate of total predator biomass in Area 48 and obtain long-term demographic dataset. The aim of this study is to update the size of these two breeding population.

New insights into the Weddell Sea Ecosystem applying a network approach

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The objective of the study is to describe the complexity and structure of the most highly-resolved Antarctic food web considering unweighted (topology-based) and weighted (interaction strength-based) analyses. Our research questions are: Do unweighted and weighted network approaches highlight different aspects of the food web structure? Does the energy of the food web flow in a compartmentalized or diffusive way? Are these two network approaches able to distinguish ‘keystone species’ in the food web? We hypothesize that: 1) weighted analyses provide a clearer understanding of the energy fluxes and species ecological roles than the unweighted ones; 2) energy flow of the ecosystem is compartmentalized in distinct modules; and 3) Antarctic krill (Euphausia superba) is a ‘keystone species’.

Sea Ice and Primary Production in the Weddell Gyre

Clara Douglas (NOC Southampton), P. Brown, N. Briggs, G. MacGilchrist, A. Naveira Garabato

Primary production is a vital part the Southern Ocean system, with the biological carbon pump contributing to driving the net carbon sink. Additionally, phytoplankton support a short but efficient food web, which provides key ecosystem services. Changes to environmental conditions will likely affect the amount of primary production that takes place in the Southern Ocean, and so it is important to understand what drives primary production and how changes

may influence the system in the future. Some of the highest rates of primary production in the Southern Ocean occur in the seasonal sea ice zone, and research suggests that primary production is greatly influenced by sea ice dynamics. Here, we have analysed data from satellites and autonomous biogeochemical floats to assess the drivers of primary production in the Weddell Gyre. We report that a significant proportion (>48%) of the inter-annual variability was explained by the area of open (ice-free) water. The length of the phytoplankton growing season is also important in predicting annual primary production. Consequently, we see that the open ocean, which experiences comparatively lower rates of primary production compared to the shelf region, but has earlier ice melt, accounts for 95% of the total carbon uptake by phytoplankton in the Weddell Gyre. Spatial patterns suggested that peak productivity is associated with the ice edge and certain regions are key hotspots for biological activity.

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