ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

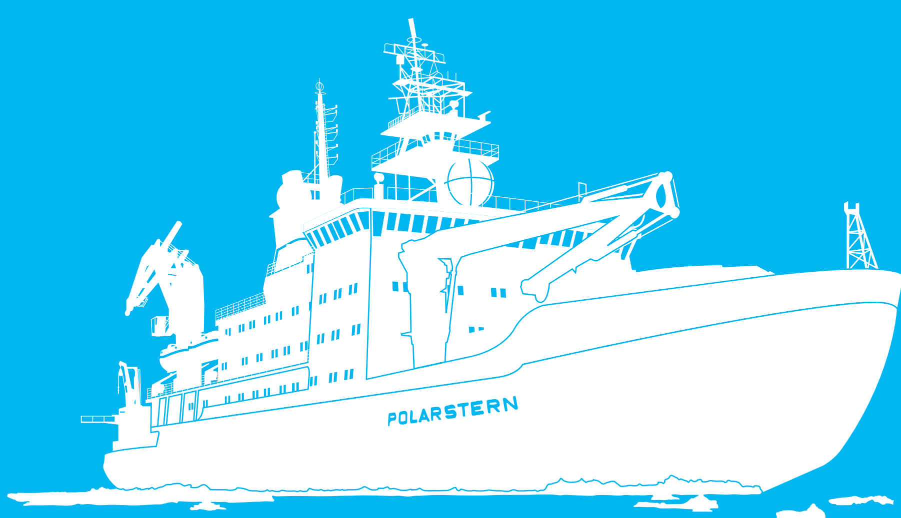
EXPEDITION PROGRAMME PS124

Polarstern

PS124
Stanley - Stanley
4 February 2021 - 30 March 2021

Coordinator: Ingo Schewe

Chief Scientist: Hartmut Hellmer



HELMHOLTZ

Bremerhaven, November 2020

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The Programme provides information about the planned goals and scientific work programmes of expeditions of the German research vessel *Polarstern*.
The papers contained in the Expedition Programme *Polarstern* do not necessarily reflect the opinion of the AWI.

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Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Hartmut H. Hellmer[1], C. Richter[1] (not on board) [1]DE.AWI

Für den Fahrtabschnitt PS124 unter dem Titel Continental Shelf Multidisciplinary Flux Study (COSMUS), wird *Polarstern* in Stanley (Falkland/Malvinas) am 4. Februar 2021 ab und am 30. März 2021 wieder anlegen. *Polarstern* wird direkt den nördlichen Bereich des Filchner-Troges (südöstliches Weddellmeer) anlaufen (Abb. 1.1), um ab Mitte Februar die Untersuchungen im Rahmen des COSMUS Projektes zu beginnen. Dabei gilt es, die in den Jahren 2013-2014 (FOS, Filchner Outflow System, PS82), 2015-2016 (FROSN, Filchner Outflow System Now, PS96) und 2018 (FROST, Filchner Outflow Systen Tomorrow, PS111) durchgeführten ozeanographischen, biologischen und bio-geochemischen Untersuchungen fortzuführen und zu ergänzen. Da die Neueisbildung spätestens in der zweiten Märzwoche keine weiteren Arbeiten in der Region zulassen wird, bleibt *Polarstern* unter anderem Zeit, auf dem 0°-Meridian bei 66°S eine den vertikalen Kohlenstofffluss aufzeichnende Verankerung auszubringen, südlich von Maud Rise für das Norwegian Polar Institute (NPI) zwei Glider aufzunehmen und vor der westlichen Kante des Ekströmisen hydrographische Messungen durchzuführen. Danach wird die *Neumayer-Station III* angelaufen, um die Überwinterer der Saison 2020 und das Bauteam aufzunehmen. Das Ablegen bei *Neumayer III* ist für den 22. März 2021 geplant (Abb. 1.1).

Im nördlichen Bereich des Filchner-Troges trifft sehr kaltes Eisschelfwasser (ISW, Ice Shelf Water) aus der Filchner-Ronne Schelfeis Kaverne auf warmes modifiziertes Tiefenwasser (MWDW, Modified Warm Deep Water) aus dem Weddellwirbel. Durch Vermischung am Kontinentalhang werden sowohl Tiefen- (WSDW, Weddell Sea Deep Water) als auch Bodenwasser (WSBW, Weddell Sea Bottom Water) gebildet (Abb. 1.2). Beide Wassermassen speisen den unteren Zweig der globalen Ozeanzirkulation und sorgen somit für die Belüftung der tiefen Schichten der Weltmeere. Eigene Verankerungsdaten aus den Jahren 2014-2018 vom östlichen Hang des Filchner Troges (76°S) haben gezeigt, dass im Jahr 2017 ein deutlich wärmerer Einstrom des MWDW über die gesamte Winterperiode andauerte. Norwegische Verankerungsdaten aus dem gleichen Zeitraum zeigen zusätzlich, dass dieses Signal bis 77°S vorgedrungen war. Modellszenarien mit dem Finite Elemente Modell FESOM projektieren klimabedingte Veränderungen der Dichtestruktur an der Schwelle des Filchner-Troges, was zu einem erhöhten Einstrom von MWDW ab Mitte dieses Jahrhunderts führen könnte. Diese Veränderungen würden in ihrem Verlauf die Zirkulation unter dem gesamten Filchner-Ronne Schelfeis beeinflussen. Sollten sich im Bereich des Filchner-Trogs vergleichbare Dichteänderungen aus den Messungen des letzten Jahrzehnts zeigen, so ließen sich die von den Modellen errechneten Ergebnisse besser in die Klimavorhersage einordnen, und die Wahrscheinlichkeit sowohl erhöhter basaler Schmelzraten des Schelfeises als auch ansteigender Einträge von Süßwasser würde sich erhöhen. Letztere haben einen großen Einfluss auf die Struktur der kontinentalen Wassersäule, die Meereisbildung und die gesamte Biologie des oberen Ozeans.

Das Vorkommen dieses relativ warmen Wassers in Zusammenhang mit ablandigen Winden könnte eine Ursache für die immer wiederkehrende Küstenpolynja östlich des Filchner-Troges sein, in deren Bereich Satellitendaten eine erhöhte Primärproduktion zeigen (Abb. 1.3). Basierend auf den Erkenntnissen aus anderen Küstenpolynjen wird vermutet, dass auch dieses Gebiet eine Kohlenstoffsenke darstellt. Sollte der Kohlenstoff durch Tiefenkonvektion in das nordwärts strömende ISW gelangen, so würde er durch die Tiefen- und Bodenwasserbildung am Kontinentalhang (Abb. 1.2) in den Tiefen des Weltozeans für Jahrhunderte gespeichert werden.

Ein weiteres Untersuchungsgebiet wird die kontinentale Schelfkante und der Schelfhang westlich der Filchner-Trogschwelle sein, um eine erneute Bestandsaufnahme zur Ausbreitung des ISW und der damit verbundenen Bildung von Tiefen- und Bodenwasser und dem weiteren Verlauf der Schelfkantenfront (Antarctic Slope Front) durchzuführen. Außerdem zeigen alle bisherigen Daten entlang der Ronne-Schelfeiskante, dass es westlich des Filchner-Troges zumindest in den Sommermonaten zu einer weiteren Ausbreitung von MWDW in einem weniger ausgebildeten Trog (Central Trough) kommen muss (Abb. 1.3). Dieser Einstrom versorgt den Kontinentalschelf mit Salz, strömt, wie die AUV (Autonomes Unterwasser Vehikel) Messungen während PS111 gezeigt haben, unter das östliche Ronne-Schelfeis und trägt dort zum erhöhten Kantenschmelzen bei.

Aus dem Vergleich der beiden Einstrom-Regionen erhoffen wir (1) Erkenntnisse bzgl. der Prozesse, die die Struktur der ozeanischen Schelfkanten-Front und die Dynamik des Einstroms von MWDW auf den südlichen Kontinentalschelf des Weddellmeeres bestimmen sowie (2) Aufschlüsse über die Rolle dieses Meeresgebietes im globalen Kohlenstoffkreislauf. Die Erkenntnisse aus PS124 sind essentiell, um die Wechselwirkung und Entwicklung des Systems Ozean-Eis-Biologie im Zeichen des Klimawandels zu verstehen und dessen globale Folgen besser vorherzusagen.

Die wichtigsten Forschungsziele der Expedition PS124 (COSMUS) sind:

- Charakterisierung der hydrodynamischen Prozesse und der Wassermassen in den Einstrom-Regionen wärmerer Wassermassen des Wedellwirbels in der Nähe der kontinentalen Schelfkante. Dabei soll die Rolle der Meeresboden-Topographie ebenso geklärt werden, wie die Raten von Tiefen- und Bodenwasserbildung unter Einbeziehung der Schmelzraten des Schelfeises.
- Die Erfassung zeitlicher Veränderungen der hydrographischen Bedingungen durch Austausch der 2018 ausgebrachten Verankerungen bei 76°, ergänzt um 3 weitere, und dem Ausbringen von Verankerungen im Bereich der Filchner-Trogschwelle in Kooperation mit norwegischen und französischen Instituten.
- Großflächige Erfassung hydrographischer Profile während der Wintermonate westlich des Filchner-Troges durch Bestückung von Weddellrobben mit Miniatur-CTDs.
- Beitrag des Antarktischen Schelfs zum globalen Kohlenstoff- und Nährstoff/ Eisen-Kreislauf. Dabei soll die biologische Kohlenstoffpumpe vom Meereis über das Pelagial bis zum Benthos synoptisch erfasst und die Rolle biotischer und abiotischer Faktoren, die Produktion und Kohlenstoff-Export von der Oberfläche in die Tiefe bestimmen, ermittelt werden.
- Die Ergebnisse leisten einen wichtigen Beitrag zu Verständnis und Vorhersage von Veränderungen der meeresbiologischen Vielfalt und Erfassung des Risikos kritischer Ökosystemleistungen. Konkret interessieren hierbei:
- Untersuchungen zur biologischen Produktion im Filchner-Ausstromsystem und zu den Energieumsatzraten im trophischen Nahrungsnetz.
- Eine Abschätzung des Einflusses von möglichen Veränderungen hydrographischer Gegebenheiten und der Schelfeisdynamik auf die Biodiversität und die Ökosystem-funktionen im Bereich des Filchner-Troges.

- Beschreibung des Meereises vor dem Filchner-Ronne Schelfeis (FRIS) durch Beschreibung der Salzgehaltsstruktur, Messung der Driftparameter und der physikalischen Eigenschaften mit Hilfe direkter Messungen und durch ein Meereis-Bojen Programm.
- Untersuchungen zur Geochemie der Sedimente.
- Erweiterte Messungen zur Belastung des Meerwassers mit Mikroplastik im südlichen Weddellmeer und Beprobung und Analyse von Robbenkot hinsichtlich des Vorkommens von Mikroplastik.

Eine genauere Beschreibung der einzelnen Arbeitsbereiche erfolgt in den weiteren Kapiteln.

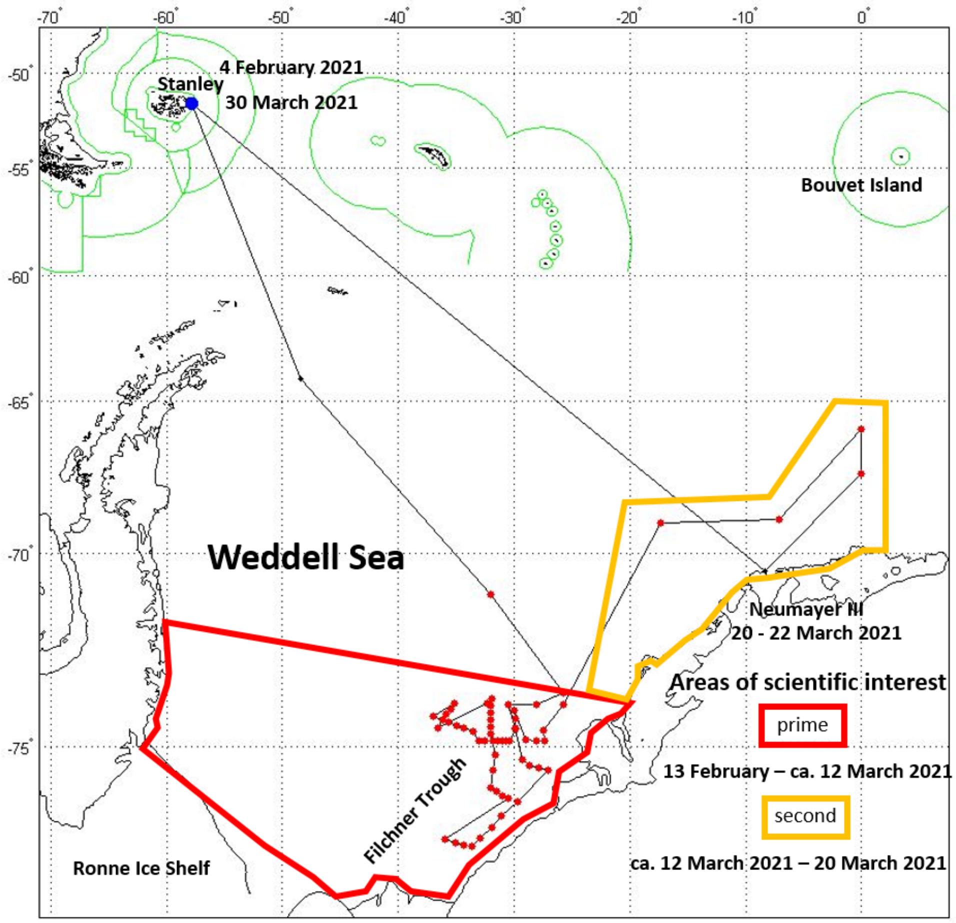

Abb. 1.1: Voraussichtlicher Fahrtverlauf und Zeitrahmen für PS124, und die Untersuchungsgebiete im südlichen (roter Rahmen) und östlichen Weddellmeer (gelber Rahmen). Die endgültigen Positionen der geplanten Stationen im südlichen Weddellmeer (rote Punkte) werden stark von der Meereisbedeckung abhängen.

Fig. 1.1: Expected cruise track and time frame for PS124 together with the areas of scientific interest in the southern Weddell Sea (red frame) and eastern Weddell Sea (yellow frame). Final positions of the stations in the southern Weddell Sea (red dots) strongly depend on the actual sea ice cover.

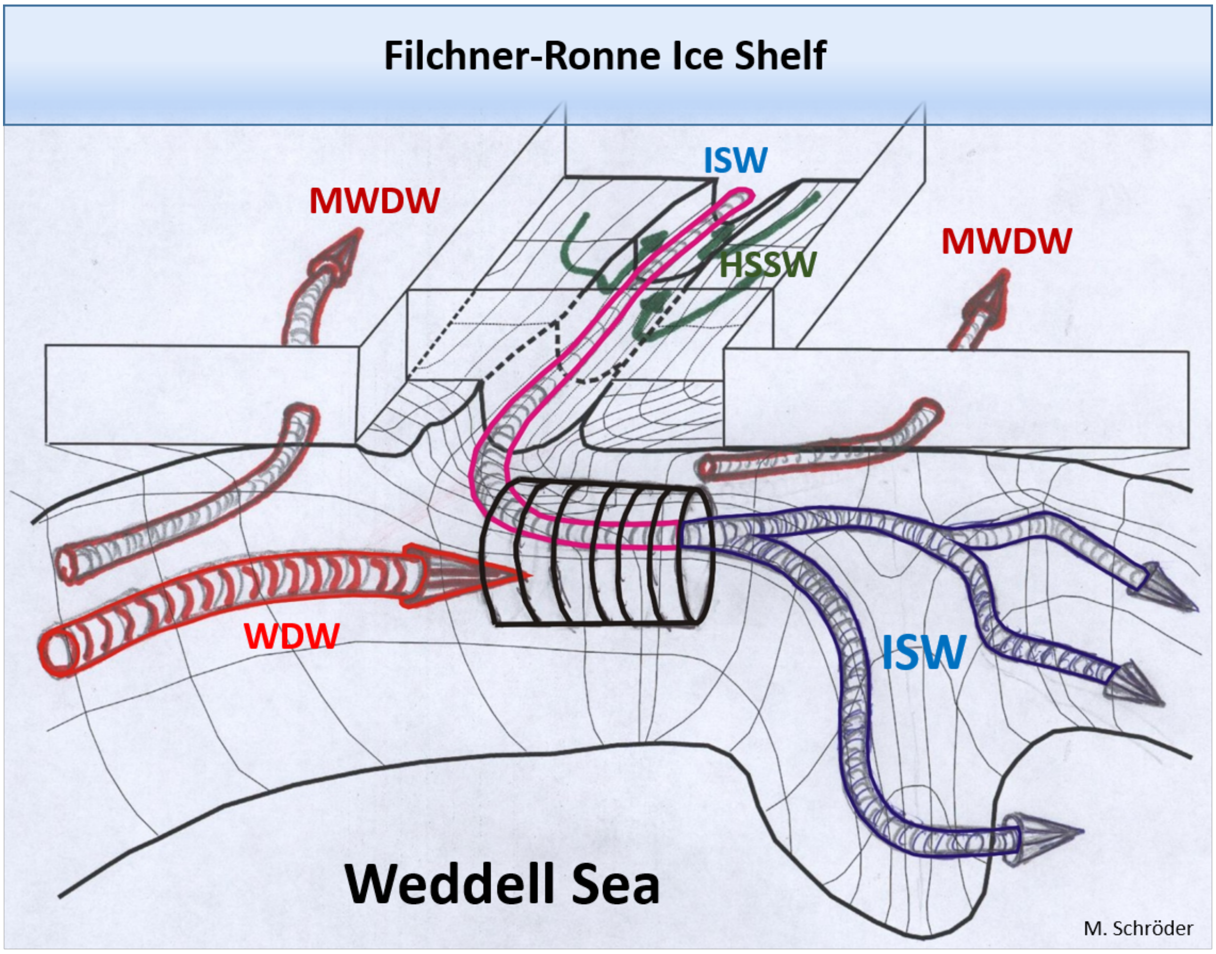

Abb. 1.2: Schematische Darstellung der charakteristischen Wassermassen des südlichen Weddellmeers und ihrer Ausbreitung und Vermischung im Bereich des Filchner-Trogs und Kontinentalhanges – Filchner-Ronne Schelfeis im Hinter-, das Weddellmeer im Vordergrund. WDW - Warm Deep Water, MWDW - Modified Warm Deep Water, ISW - Ice Shelf Water, HSSW – High Salinity Shelf Water.

Fig. 1.2: Schematic presentation of the characteristic water masses in the southern Weddell Sea together with spreading pathways and mixing in the northern Filchner Trough and the continental slope. Filchner-Ronne Ice Shelf in the back and Weddell Sea in the front. WDW - Warm Deep Water, MWDW - Modified Warm Deep Water, ISW - Ice Shelf Water, HSSW – High Salinity Shelf Water.

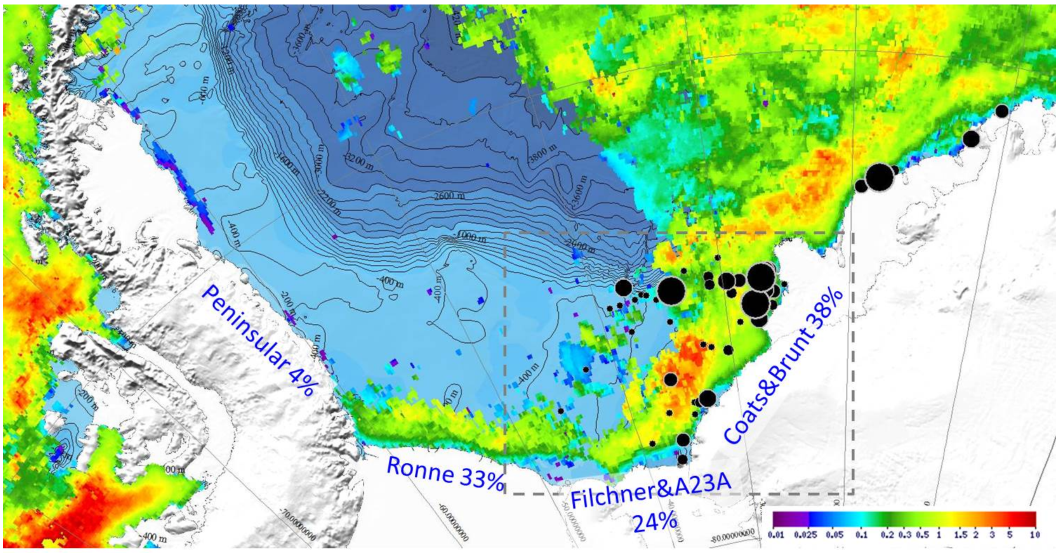

Abb. 1.3: Bodentopographie des südlichen Weddellmeeres überdeckt von Chlorophyll-a Konzentrationen im offenen Wasser (mg/m³, VIIRS, klimatologisches Mittel aus Dez-Feb 2012-2017), keine Daten auf Grund von Meereisbedeckung. Schwarze Punkte markieren Untersuchungsstationen für benthische Fauna, ihre Größe skaliert mit der faunischen Biomasse biomass (0.5 to 20 g C m^{-2}, Proben genommen während PS82-PS96). Angegeben auch der relative Beitrag von 4 Polynjen zur Meereisproduktion im südlichen Weddellmeer (Antarktische Halbinsel, Ronne-Schelfeis, Filchner-Schelfeis mit Eisberg A23A, Brunt Schelfeis mit Coats Land, Werte aus Paul et al, 2015). Der grau gestrichelte Rahmen markiert in etwa das in Abb. 1.2 dargestellte Gebiet.

Fig. 1.3: Topography of the southern Weddell Sea overlaid with chlorophyll-al concentration in open waters (mg/m³, VIIRS, climatological mean Dec-Feb 2012-2017), no values for sea-ice covered regions. Black dots denote sampling sites for benthic fauna. Dot size scales with fauna biomass (0.5 to 20 g C m^{-2}, samples from PS82-PS96). The relative contribution of sea-ice formation amongst the 4 polynya regions is annotated (Antarctic Peninsula, Ronne Ice Shelf, Filchner Ice Shelf including Iceberg A23A, Brunt Ice Shelf including Coats Land, values from Paul et al, 2015). Grey square marks boundaries of map in Fig.1.2.

SUMMARY AND ITINERARY

For the cruise PS124-COSMUS (Continental Shelf Multidisciplinary Flux Study), *Polarstern* will depart on 4 February 2021 and arrive on 30 March 2021 in Stanley (Malvinas / Falkland). *Polarstern* will steam directly to the northern Filchner Trough region (south eastern Weddell Sea; Fig. 1.1) to start with the field measurements proposed in the framework of the COSMUS project. This work can be considered a continuation and extension of the oceanographic, biologic, and bio-geochemical studies carried out in austral summers 2013-2014 (FOS, Filchner Outflow System, PS82), 2015-2016 (FROSN, Filchner Outflow System Now, PS96), and 2018 (FROST, Filchner Outflow System Tomorrow, PS111). It is expected that new sea ice formation will shut-down sampling operations in the southern Weddell Sea by the second week of March. Therefore, enough ship time will be left for activities in the eastern Weddell Sea such as for deployment of a vertical carbon flux monitoring mooring on the Greenwich Meridian at 66° S, recovery of two NPI (Norwegian Polar Institute) gliders south of Maud Rise, hydrographic measurements at the western edge of Ekströmisen, and, finally, pick-up of last-season's overwinters and the construction team from *Neumayer Station III*. *Polarstern* will depart from *Neumayer III* on 22 March 2021 (Fig. 1.1).

The northern part of the Filchner Trough is the location where super-cooled Ice Shelf Water (ISW) from underneath the Filchner-Ronne Ice Shelf encounters modified Warm Deep Water (MWDW) originating from the rim of the Weddell Gyre. The mixing of both water masses at the continental shelf break forms Weddell Sea Deep Water (WSDW) and Weddell Sea Bottom Water (WSBW) (Fig. 1.2). Both waters contribute to the lower limb of the global thermohaline circulation and, thus, ventilate the bottom layers of the World Ocean. AWI mooring records from 2014-2018 from the eastern slope of the Filchner Trough at 76° S reveal an exceptionally warm and prolonged flow of MWDW toward the Filchner Ice Shelf in 2017. Norwegian mooring data from the same period documents this event as far south as 77° S. Model projections with the Finite Element Model FESOM show that the density structure at the sill of the Filchner Trough might change such that, starting in the second half of this century, 'unmodified' WDW might enter the trough continuously with severe consequences for the whole circulation beneath Filchner-Ronne Ice Shelf. If our observations near the sill will show similar density changes, our model results should be suitable to increase credibility in terms of (1) climate change projections for this remote region, (2) enhanced basal melt rates, and (3) increased fresh water fluxes. Fresh water fluxes substantially impact water column stability, sea ice formation, and upper ocean biology on the continental shelf and beyond.

The appearance of relative warm water combined with off-shore winds might favor a recurring coastal polynya east of the Filchner Trough, where satellite data generally shows high primary productivity during austral summer (Fig. 1.3). Based on studies from other Antarctic coastal polynyas, this area can be expected to be a significant carbon sink. If deep convection entrains the carbon into the northward flowing ISW, deep and bottom water formation at the continental slope (Fig. 1.2) would export the carbon to be stored in the deep global ocean for centuries.

An additional area of interest will be the continental shelf break and slope west of the Filchner Trough sill. The region awaits a new inventory of the spreading of ISW and related deep and bottom water formation, and the westward continuation of the Antarctic Slope Front. In addition, all austral summer measurements from the Ronne Ice Shelf front indicate that MWDW enters the southern continental shelf west of the Filchner Trough via the less pronounced

Central Trough (Fig. 1.3). AUV (Autonomous Underwater Vehicle) measurements carried out during PS111 show that this MWDW enters the eastern Ronne Ice Shelf cavity causing enhanced melting near the ice shelf front.

We expect the investigation of both MWDW inflow regions to (1) constrain and understand the processes, which determine the structure of the slope front and control the dynamics of the MWDW flow onto the southern Weddell Sea continental shelf, and (2) reveal the importance of the region for the global carbon flux/storage. The results of PS124 will be essential for our understanding of (1) the interaction and the development of the ocean-ice-biology system in a changing climate and (2) an improved projection of the global consequences of climate change in this remote location.

Important goals of the expedition PS124 (COSMUS) are:

- Characterisation of hydrographic features and water masses of the Filchner-Ronne Outflow System, the role of bathymetry for current pathways, and the deep and bottom water formation rates at the continental slope.
- Monitoring time variations of hydrographic conditions on the eastern flank of the Filchner Trough by means of re-deployment of 3 moorings at 76°S, complemented by 3 additional moorings, and (re)-deployment of several moorings near the Filchner Trough sill in cooperation with institutes from Norway and France.
- Wide-range hydrographic profiling during austral winter west of the Filchner Trough by means of CTD-tagged Weddell Seals.
- Quantification of the Antarctic continental shelf's contribution to global carbon and nutrient/iron budgets, assessing the biological carbon pump by dissecting biotic and abiotic controls of ocean productivity and carbon exports from the surface ocean to the deep.
- Understanding and predicting the change of marine biological diversity and assessing the risk for critical transitions in marine ecosystem functionality.
- Investigation of the biological production of the Filchner Trough region and the high-energy turnover to subsequent trophic levels.
- Estimating the impact of possible changes in the hydrography and shelf and sea ice dynamics on biodiversity and ecosystem functioning of the southern Weddell Sea.
- Compilation of data on distribution patterns of pack ice seals in the Filchner Trough region.
- Describing the sea ice in front of the Filchner-Ronne Ice Shelf (FRIS) by measuring salinity, drift velocity and other physical parameters together with a sea ice buoy programme.
- Investigation of the geochemical content of the sediments.
- Measuring the micro-plastic content of seawater in the southern Weddell Sea.

A more detailed description of work of the different groups follows in the next chapters.

2. OCEANOGRAPHIC CONDITIONS AND DISTRIBUTION OF OCEANIC TRACE GASES NEAR THE SILL OF FILCHNER TROUGH, SOUTHERN WEDDELL SEA

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Objectives and methods

The Filchner Trough in the southeastern Weddell Sea is the main conduit for northward flowing Ice Shelf Water (ISW), defined by temperatures below the surface freezing point (Fig. 1.2). ISW originates from High Salinity Shelf Water (HSSW), formed on the continental shelf in front of Ronne Ice Shelf, and carries the glacial melt from the Filchner-Ronne Ice Shelf (FRIS). The ISW pathway within the trough varies on seasonal time scales with flow out of the Filchner Ice Shelf cavity occurring on the western slope only during late summer/early fall (Darelius and Sallee 2018). On its way to the continental shelf break, ISW encounters a seasonal inflow of Modified Warm Deep Water (MWDW), flowing along the eastern slope of the trough towards the ice shelf front (Ryan et al. 2017, 2020). ISW dominates at the trough's sill where mixing with open ocean waters forms the deep and bottom waters of the Weddell Sea, the former being the precursor of Antarctic Bottom Water and thus one of the main contributors to the lower branch of the global thermohaline circulation (Foldvik et al. 2004). Projections based on the output of our coupled sea ice–ocean-ice shelf models indicate that in the near future the density of HSSW and, thus, of ISW at the Filchner Trough sill might decrease such that unmodified Warm Deep Water (WDW) can enter the trough and penetrate into the deep FRIS cavity (Hellmer et al. 2012, 2017). The presence of WDW underneath FRIS, similar to the ice shelves fringing the Amundsen Sea to date, is bound to cause a dramatic increase in basal melting. The latter changes ice shelf thickness, reduces the buttressing effect of bottom topography and ultimately influences the dynamics of the ice streams draining the West and East Antarctic Ice Sheets (Timmermann and Goeller 2017). The resulting fresh water input will have a profound impact on the structure of the shelf water column, the sea ice cover, the formation of deep and bottom waters, and melting at the base of ice shelves located downstream (Timmermann and Hellmer 2013).

This expedition is closely connected to our ongoing monitoring of hydrographic properties beneath the Filchner Ice Shelf in the framework of the Filchner Ice Shelf Project (FISP). The fieldwork is designed to (a) extend existing data sets from the southern Weddell Sea continental shelf, necessary for the initialization and validation of our coupled ice shelf - ice sheet models (FESOM), and (b) build-up a reference data set to identify changes within the ocean/ice shelf/sheet system, expected to occur due to climate change.

General objectives:

- Specify the controls on slope front dynamics and flow of water masses of open ocean origin onto the southern Weddell Sea continental shelf.
- Determine the temporal variability of the hydrography and tracer distribution in the Filchner Trough with regard to ISW outflow, AABW formation, and southward propagation of MWDW.
- Identify temporal trends by means of mooring observations.
- Provide a comprehensive dataset for numerical model validation and initialisation of coupled ocean - ice shelf - ice sheet models.

Specific objectives:

- Determine the characteristics and dynamics of the slope current in the southern Weddell Sea.
- Monitor the flow of MWDW onto the southern Weddell Sea continental shelf.
- Identify ISW pathways out of the Filchner Trough and along the continental slope.

The combination of ship- and sea ice-based CTD casts combined with long-term moorings in the Filchner Trough and beneath the Filchner Ice Shelf aims at describing the present physical environment in the southern Weddell Sea, and to monitor its variability and trends. Tracer observations will help to quantify:

- AABW formation (transient trace gases [CFCs] to identify transit time scales and formation rates), and
- interannual variability by comparison with previous expeditions (e.g., PS96 in 2015-2016 and PS111 in 2018).

Work at sea

After transit to the target area, measurements will be carried out with the CTD/water bottle system to acquire hydrographic data and water samples as outlined in Fig. 2.1. A maximum of 100 ship-based CTD-casts, and another 30 helicopter-based CTD casts are planned to survey the region. From the full-depth profiling casts, we intend to obtain about 1,000 water samples for CFCs analyses. To meet our objectives it is necessary to have stations/transects (1) normal to the Filchner Trough axis, (2) across the Filchner Trough sill, and (3) across the slope front and down the continental slope following the path of ISW/WSBW. The total station time of this proposal amounts to ca. 7 days (Fig. 2.1; helicopter operations are not assumed to consume relevant ship time). In order to increase the temporal and spatial CTD coverage, 12 Weddell Seals will be tagged to 'operate' on the ice-covered southwestern continental shelf during the austral winter months (see chapter 3).

Water samples for CFC measurements will be stored in 100 ml glass ampoules and will be sealed off after a CFC-free headspace of pure nitrogen has been applied. The CFC samples will be later analyzed in the CFC-laboratory at the IUP Bremen.

The other major operational effort is the recovery, deployment, and re-deployment of moorings operated by different institutions (Fig. 2.1). The re-deployment of three moorings at 76° S, deployed on the eastern flank of the Filchner Trough in 2018/PS111 (red squares in Fig. 2.1) and aimed to monitor the interplay between the southward flowing MWDW and the northward flowing ISW, will be complemented by two near-by 'pipe moorings', designed to allow measurements of the upper water column, and one additional 'standard' mooring at the western end of the 76° S-transect. These moorings will continue the time series initialized in 2013/PS82. These records helped to identify the strong seasonality of MWDW intrusions (Ryan et al. 2017), and showed an 'Exceptionally Warm and Prolonged Flow of Warm Deep Water toward the Filchner-Ronne Ice Shelf in 2017' (Ryan et al. 2020). All moorings will operate over a time span of 2 to 4 years. In cooperation with LOCEAN (Paris), NORCE (Bergen), and University Bergen, 10 moorings will be recovered across the continental shelf east of the Filchner Trough sill along roughly 75° S and two moorings at the continental slope to the north (Fig. 2.1). The number of moorings on the 75° S-line will be reduced to three from NORCE and four from LOCEAN, while at the continental slope two from University Bergen will be re-deployed to monitor the dynamics and the variability of the slope current. Finally, a RAFOS array with 3 sound sources will be installed along the 2000-m isobath off Brunt Ice Shelf to guide profiling APEX floats, expected to monitor hydrographic properties around the Antarctic Slope Front and onshore flow of open ocean waters.

As growing sea ice will likely terminate the sampling efforts in the southern Weddell Sea around the second week of March, the remaining time (roughly two weeks) will be used to deploy one mooring west of Maud Rise on the Greenwich Meridian at 66° S designed to monitor vertical carbon fluxes, to pick-up two gliders from the Norwegian Polar Institute, and to repeat CTD measurements near the western front of Ekströmisen.

Fig. 2.1: Map of historic (black dots) and expedition specific (color dots) CTD-stations and positions of operating moorings in the southern Weddell Sea. Color code according to the legend (see inset) with PSxx = Polarstern expedition, SS = sound source, 76 = 76° S, UB = NORCE and University Bergen, JB = LOCEAN.UPMC.

Preliminary (expected) results

- Improved understanding of the slope front dynamics in the southern Weddell Sea.
- Extension (by three years) of the time series (2013-2018) on the eastern slope of the Filchner Trough based on mooring data from the 76° S-transect.
- Extended information about the temporal variability and strength of the southward flowing MWDW on the eastern slope of the Filchner Trough.
- Improved understanding of the spreading and pathways of ISW in the Filchner Trough and beyond the Filchner-Trough sill.

The results will be highly relevant to the new Helmholtz Research Programme "Changing Earth – Sustaining our Future" Subtopic 2.3 (Sea level Change).

Data management

Soon after the end of the expedition, a final calibration of the hydrographic data will be done using standard procedures. The preparation of the CFC samples as well as the analysis and accurate quality control will be carried out in the labs of the IUP Bremen. Once published, all data sets will be transferred to data archives such as PANGAEA Data Publisher for Earth & Environmental Science (www.pangaea.de) or send to the German Oceanographic Data Center (DOD), where they are available for the international scientific community. PANGAEA guarantees long-term storage of the data in consistent formats and provides open access to data after publication.

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

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3. SEALS AND OCEANOGRAPHY AT THE FILCHNER-RONNE SHELF ECOSYSTEM (SEAROSE)

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Outline

Seals and oceanography at the Filchner-Ronne shelf ecosystem (SEAROSE) is an integrated element within the oceanographic investigations of *Polarstern's* COSMUS expedition (*cf*. chapter 2). SEAROSE contributes instrumentation of Weddell seals (*Leptonychotes weddellii*) with conductivity, temperature, depth (CTD) Satellite Relay Data Loggers (CTD-SRDL). Deployments of CTD-SRDLs are of particular relevance over the continental shelf break and slope west of the Filchner Trough sill. This region requires a new inventory of the spreading of Ice Shelf Water (ISW) and related deep and bottom water formation, and the westward continuation of the Antarctic Slope Front. The region is comparatively data deficient and instrumented seals can provide *in-situ* hydrographic data along their foraging excursions to fill this gap - in particular during winter. Furthermore, the expedition allows to extend data on the distribution of seals from earlier investigations (PS82 in 2014) over the ice-covered southern continental shelf west of the Filchner Trough towards the Central Trough (*cf*. Fig. 3). Ship-board and dedicated small-scaled seal census helicopter surveys are therefore envisaged to be carried out. This data set also provides a ground truthing opportunity to compare the occurrence of seals based on counts derived from visual observations with those derived from algorithm-based detection of seals on high resolution satellite images.

3.1 Instrumentation of Weddell seals

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Objectives

This approach concentrates on deployments of CTD-SRDLs on seals on sea ice in order to get data on the seals' foraging behaviour and concurrent hydrographic data over the continental shelf break and slope west of the Filchner Trough sill. Recent publications provide evidence for extended residence times of satellite tracked Weddell seals (*Leptonychotes weddellii*) in the wider area of the Filchner Trough (Nicholls et al. 2008; Årthun et al. 2012; Nachtsheim et al. 2019; Photopoulou et al. 2020). Satellite tracking of marine mammals in the Southern Ocean relies on the ARGOS system. ARGOS satellite transmitters for marine mammal applications are designed to provide the animals' at-sea locations and transmit data to the satellites when the seals surface. CTD-combined ARGOS satellite-relayed dive loggers have the capability to record *in-situ* water temperature and conductivity for the entire migration of tracked seals. The data is of suitable quality to characterise the oceanographic settings used by seals (e.g., Nicholls et al. 2008; Boehme et al. 2009; Meredith et al. 2011), and are complementary to the oceanographic investigations described in chapter 2. Devices will be deployed on the seals' head after completion of the seals' annual moult and they will shed the tags again the following year during the annual moult resulting in satellite tracks and concurrent behavioural and hydrographic data to be collected over a year at maximum. Due to adult Weddell seal males "maritorial" behaviour, they can be expected to remain within the investigation area throughout the year and will, therefore, be the preferred gender to be instrumented with CTD-SRDLs. Weddell seals have the potential to dive to depths of greater than 1,200 m (Photopoulou et al. 2020) and hence profile the entire water column in the investigation area. Furthermore, their foraging dives also yield indirect information on both potential pelagic and demersal or benthic prey. The deployments of CTD-SRDLs will preferably take place after the seals have completed their annual moult. The devices will be glued to the new fur of anaesthetized seals using quick setting epoxy resin. For the purpose of instrumentation, the seals need to be anaesthetized following the methods as described in Bornemann et al. (1998); Bornemann and Plötz (1993), and Bornemann et al. (2013). Drugs are initially administered intramuscularly by remote injection using blow-pipe darts. Follow-up doses are usually given intramuscularly by direct manual injection or in rare cases intravenously. The dose regime involves the drugs as listed below and dosages or respectively dose ranges vary depending on initial or follow-up injections. The seals will be immobilized with ketamine/xylazine or with tiletamine/zolazepam combinations. Depending on the course of the immobilisation, dosages need to be individually adjusted and will be complemented by the same drug to maintain or extend the immobilisation period on demand. The benzodiazepine diazepam may be needed to attenuate muscle tremors typically induced by ketamine. Atipamezol will be used to reverse the xylazine component in the xylazine/ketamine immobilisation, and flumazenil may be used as antidote for the unlikely situation of an overdose of benzodiazepines. Doxapram is exclusively reserved for the unlikely necessity to stimulate breathing in the case of extended periods of apnoea, when mechanical obstructions of the upper airways can be excluded. The length and girth of each seal will be measured and a suite of samples taken. The mass of the seal and the dosages will be determined in a *post-hoc* calculation via photogrammetry (de Bruyn et al. 2009). In case of heavy ice conditions that may hamper *Polarstern* to the Filchner Trough, an alternative survey will be carried out along the east coast of the Weddell Sea. This would also include potential instrumentation of Weddell seals with cameras.

Work at sea

Up to 12 CTD-SRDLs will be deployed preferably on adult male Weddell seals to study their foraging behaviour, and their profiling dives will allow sampling of concurrent data on Conductivity, Temperature at Depths in order to complement the oceanographic investigations and to provide information on the seals' foraging at depth. Additionally, a blood sample of 30 ml will be taken together with hair and whisker samples, and opportunistic samples of scats, naturally regurgitated vomitus and seawater. Blood samples will be centrifuged on board, separated in red blood cells and serum and both deep frozen at -30°C. Within the serum fraction we aim to analyse for prey specific biomarker proteins that allow for reconciliation with the seals' prey spectrum (e.g. octopine in octopods, specific amines in fishes, homarines and dimethylsulfonio-propionate in molluscs and crustaceans) in later laboratory analyses (*cf.* Hochachka et al. 1977; Ito et al. 1994; Eisert et al. 2005; Eder et al. 2010), while genetic investigation of scats and vomitus can provide species specific hints on prey items. The data can recall the recent prey spectrum within a couple of days prior to blood sampling. The hair and whisker samples will be used to get retrospective information on the prey spectra on intermediate time scales up to a couple of months by means of stable isotope analyses (*cf*. Lewis et al. 2006; Newsome et al. 2010; Hückstädt et al. 2012a; Hückstädt et al. 2012b; Beltran et al. 2016; Goetz et al. 2017; Brault et al. 2019; Lübcker et al. 2020). *In-situ* collection of naturally regurgitated vomitus, faecal samples, and seawater for investigations of microplastics (*cf*. chapter 11) complement the sampling protocol.

Expected results

From each of the CTD-SRDL tagged seals, we expect per day about four temperature, salinity and depth profiles almost in real time which will allow us to study how changes in the underwater environment alter prey distribution beneath sea ice as indicated by the seals' individual diving and foraging behaviour. We furthermore expect that these key physical oceanographic variables collected from hitherto under-sampled coastal shelf seas may assist the refinement of coupled ocean-sea ice-ice shelf models of the Southern Ocean. Sampling of blood and other material will provide information on the seals' prey spectrum in later laboratory analyses.

Data management

All data and related meta-information will be made available in open access via the Data Publisher for Earth & Environmental Science PANGAEA (https://www.pangaea.de), and will be attributed to a consistent project label denoted as "Marine Mammal Tracking" (MMT, see https://www.pangaea.de/search?q=project:label:mmt). Furthermore, data will be made available for the IPY follow-up programme Marine Mammals Exploring the Oceans Pole to Pole (MEOP; http://www.meop.net/) and Movebank (www.movebank.org).

3.2 Helicopter and ship-based seal surveys

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Objectives

This approach concentrates on an aerial seal census survey over ice covered ocean in order to get data for density estimates of seals west of the Filchner Trough. Historically, methods for seal census surveys comprise a high degree of heterogeneity, which restricts the comparability of data taken with different methodological approaches. In order to ensure that novel findings can be compared with those from earlier surveys, we aim to survey using the exact same methods applied in the only recent data set that is available for the Weddell Sea. This data set was generated by Bester and Odendaal (1999, 2000) from aboard *Polarstern* in 1998 during the multinational circum-Antarctic wide Antarctic Pack Ice Seal (APIS) Programme of SCAR (Southwell et al. 2012; Gurarie et al. 2017), and is comparable in its methods with earlier seal surveys that were carried in the eastern Weddell Sea by Bester et al. (1995; *cf*. Erickson et al. 1993). Methodologically congruent surveys were in particular performed during *Polarstern* expedition PS82 in 2014 (Bester et al. 2014) and indicate increasing densities west of the Filchner Trough with highest density predictions for Weddell seals near the shelf break (Oosthuizen et al. in review).

Such data on marine top predator abundance and distribution are key for the design and management of Marine Protected Areas, e.g. the Weddell Sea MPA (*cf*. Teschke et al. 2020). Although being the greatest consumers of krill and fish in the Southern Ocean, our understanding of the status and trends of pack-ice seal populations and their relationship with key habitat characteristics, such as sea ice, still represents a major knowledge gap, and until now, it has been logistically too challenging and expensive to conduct regular pack-ice seal surveys at a spatial scale sufficient for assessing their abundance and distribution even on regional scale. As a result, the chance for an analysis or even an estimate of trends against earlier seal counts conducted in only small longitudinal sectors of the Southern Ocean between 1960s and 1990s are nil. Only a concerted action can hence provide an opportunity to serve for the aforementioned needs of a Southern Ocean wide assessment, which is aspired by the international initiative “Censusing Animal Population from Space” (CAPS). CAPS is an integrated SOOS initiative, and with its SCAR related APIS II reassessment intended to facilitate and develop the use of high-resolution satellite imagery to provide population status data for Antarctic seals. The interpretation of satellite images requires a preparatory ground truthing in order to reconcile observer-based counts and image data taken by aircrafts or helicopters and satellites on spatially and temporally synchronous tracks. This reconciliation allows to develop algorithms for the identification of seal specific differences in contours, brightness and contrasts for automated image analysis, and hence allows to determine the detection probability for seals in automated image analyses.

Work at sea

The helicopter line transect survey design will be adjusted according to sea ice conditions. Under ideal weather conditions, up to 10 transects of up to 120 min duration each will be flown at a height of 200 feet (~60 m) and at a velocity of 60 knots (~110 km/h) over sea ice. Transects should not exceed 35 km distance from each other, and shall be ideally flown perpendicular to the 1,000 m bathymetric contour. Seals will be counted by two observers through sighting bars attached to the windows on each side of the back seats of the helicopter. Flight times and GPS locations will be noted at 10 min intervals, and sightings (counts) in units of three minutes. Counts will be made in conjunction with the date, time, location of each observation, sea ice concentration and eventually ice floe sizes, and photos of sea ice will be taken by a third observer in the co-pilot seat. Seal counts will be done through two sighting bars made from polycarbonate, fastened by suction caps at each of the side windows of the helicopter (*cf*. Bester & Odendaal 1999, 2000; Bester et al. 2014). Physical check marks on the sighing bars delineate six virtual census strips denoted as bins (when being projected on the ice) and represent vertical angle intervals at 10°, the innermost angle (30° from vertical) being treated as the centreline of the transect by each observer, and the outermost bin stretching to the horizon. Thus, five intervals are created corresponding to strip widths of 53, 71, 108, 204 and 587 feet (16, 22, 33, 62 and 179 m) on the ice on each side of the helicopter, the outermost (6^{th}) bin (1,135 feet / 346 m) stretching to the horizon (*cf*. Bester et al. 2014). These are connected by an obscure strip (bin) underneath the helicopter of 230 feet (70 m). The bins are used to estimate the perpendicular distances at which seals, or groups of seals, are seen from each side of the helicopter. In order to calibrate the sighting bars to each observer, the helicopter will fly over flagged marker poles that will be laid out on ice along the aforementioned predefined bin distances.

The seal census protocol explained above enables the survey personnel to identify seals sighted to species level and to calculate adjusted density estimates for the seals found in the survey area. It is mandatory that the flights correspond with the seals’ haulout maxima on the ice peaking between 12:00 - 13:00 local apparent time (LAT). Thus, transects need to be scheduled for between 11:00 (starting) and 16:00 (ending) approximate (LAT). Since the core investigation area west of the Filchner Trough is located *ca* -3h relative to UTC, the flights should be scheduled between 14:00 and 19:00 UTC. We furthermore consider doing ship-board strip surveys (Condy 1977; Bester et al. 1995). Though such surveys are biased and no conclusions as to the actual distribution and abundance of the various seal species can be drawn (Bester and Odendaal 2000; Southwell et al. 2012), this will, however, provide opportunities to locate seals on sea ice, and to broadly compare with results from similar ship-board surveys during earlier expeditions (e.g. Condy 1976, 1977; Bester et al. 1995; Bester and Odendaal 2000; Bester et al. 2019; Bester et al. 2020).

Expected results

We expect sightings of crabeater seals (*Lobodon carcinophaga*), Weddell seals (*Leptonychotes weddellii*), leopard seals (*Hydrurga leptonyx*) and Ross seals (*Ommotophoca rossii*). By mapping occurrences of seals on sea ice, this survey will contribute to the interpretation of top predator aggregations within and west of the Filchner Trough, and, furthermore, by reconciling observer-based detections of seals on ice with those spotted on satellite images, can provide ground truthing data to train algorithms for automated detections of seals on large-scale image series. However, a major challenge is to synchronize the seal survey with high-resolution satellite images to be taken by WorldView satellites. In case of unfortunate ice conditions that may hamper *Polarstern* to reach the investigation area at the Filchner Trough, an alternative survey will be carried out along the east coast of the Weddell Sea.

Data management

All data and related meta-information will be made available in open access via the Data Publisher for Earth & Environmental Science PANGAEA (www.pangaea.de), and will be attributed to a consistent project label denoted as "Marine Mammal Tracking" (MMT, see https://www.pangaea.de/search?q=project:label:mmt).

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4. BATHYMETRY OF THE SOUTHERN WEDDELL SEA CONTINENTAL SLOPE

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Grant No. AWI_PS124_06

Objectives

Accurate knowledge of the seafloor topography, hence high-resolution bathymetry data, is key basic information necessary to understand many marine processes. It is of particular importance for the interpretation of scientific data in a spatial context. Bathymetry, hence geomorphology, is furthermore a fundamental parameter for understanding the general environment setting of an area. In addition, bathymetry and bathymetry-derived products are essential to understand geological processes such as erosion, sediment transport and deposition, and for the characterisation of habitats. Bathymetry can be complemented by video-graphic data and high-resolution sub-bottom data, adding the third dimension to bathymetric maps.

While global bathymetric maps give the impression of a detailed knowledge of worldwide seafloor topography, most of the world’s ocean floor remains unmapped by hydro-acoustic systems. In these areas, bathymetry is modelled from satellite altimetry with a corresponding low resolution. Satellite-altimetry derived bathymetry lacks the resolution necessary to resolve small- to meso-scale geomorphological features (e.g. sediment waves, glaciogenic features and small seamounts). Ship-borne multibeam data provide bathymetric information in a resolution sufficient to resolve those features.

Bathymetry data in combination with sub-bottom information, can be used to optimise the on-site sampling strategy and support survey planning for towed equipment. For example, areas of outcropping older strata and areas of reduced or enhanced sediment accumulation can be identified.

Perennial sea ice cover in the southern Weddell Sea renders much of the seafloor unexplored and unmapped. This research expedition provides the opportunity to collect high-resolution bathymetry data and shed light on pending scientific research questions. We aim to take the opportunity to map the unexplored area west of the Filcher Trough. Therefore, ship- and OFOS based micro-bathymetric analyses of seafloor will be performed using the ships hydro-acoustic instruments, as well as multibeam and sonar systems deployed with the OFOS.

Work at sea

Bathymetric data will be recorded with the hull-mounted multibeam echosounder Atlas Hydrosweep DS3, and sub-bottom data will be recorded with the hull-mounted sediment echosounder Atlas Parasound P70. The main task of the bathymetry group is to plan and run bathymetric surveys in the study areas and during transit. The raw bathymetric data will be corrected for sound velocity changes in the water column and further processed and cleaned for erroneous soundings and artefacts. Simultaneously recorded sub-bottom data provide information on the sedimentary architecture of the surveyed area. High-resolution seabed and sub-bottom data recorded during the survey will be made available for site selection and cruise planning.

Preliminary (expected) results

Expected results will consist of high-resolution seabed maps and sub-bottom information along the cruise track and from the target research sites. Expected outcomes aim towards a better understanding of the geological and, particularly, the sedimentary processes in the research area.

Data management

Environmental data will be archived, published, and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (www.pangaea.de) within two years after the end of the cruise at the latest. By default the CC-BY license will be applied. Hydro-acoustic data (multibeam and sediment echosounder) collected during the expedition will be stored in the PANGAEA data repository at the AWI. Furthermore, the data will be provided to mapping projects and included in regional data compilations such as IBCSO (International Bathymetric Chart of the Southern Ocean) and GEBCO (General Bathymetric Chart of the Ocean).

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

5. SEA ICE GEOPHYSICS AND BIOGEOCHEMISTRY

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Grant No. AWI_PS124_08

Objectives

Antarctic-wide changes of sea-ice extent and in particular variations in the Ross, Amundsen, and Bellingshausen Seas have been linked to variations of stratospheric circulation (e.g. Turner et al. 2006; Thompson et al. 2011) or to the freshening of the Southern Ocean by ice shelf melt waters (e.g. Bintanja et al. 2013). However, recent studies on sea-ice drift around Antarctica have shown that, e.g., in the Weddell Sea (WS) wind-driven thermodynamic changes in ice advection are the dominant drivers for the current evolution of sea-ice concentration (Holland and Kwok 2012). The sea-ice extent in the WS has slightly declined during winter, but strongly increased during summer (Turner et al. 2015; Hobbs et al. 2016), although recent summers have seen a sharp drop (e.g. Vernet et al. 2019; Turner et al. 2020). This mean decrease in cyclonicity of the sea-ice cover points toward a deceleration of the Weddell Gyre (Holland and Kwok 2012), suggesting increasing amounts of thick, second-year ice. In addition, deformation caused by sea-ice drift might lead to a significant increase in sea-ice thickness, in particular in coastal regions (e.g. Schwegmann 2011), but provides also surface features for strong snow ablation. However, a more detailed interpretation and analysis is hampered by the lack of observational data of ice drift and thickness as well as snow characteristics, which is urgently required for model development and satellite data analysis. Sea ice plays a crucial role for the production of dense waters, and the amount of sea ice formed on and exported from the southern WS continental shelf is a robust indicator for the amount of brine expelled in the region to support bottom water formation (Nicholls et al. 2009). The amount of ice formed and exported depends both on thermodynamic processes and ice deformation. While satellite remote sensing can be used to observe thin ice formed in polynyas (Paul et al. 2015), there is presently no reliable method that could remotely estimate the export of thicker ice further downstream. In this regard, the use of drifting buoys and electromagnetic ice thickness measurements are particularly important.

In addition to ice growth and deformation, snow on sea ice significantly modifies the sea ice mass balance. However, there is still insufficient information about snow thickness and metamorphism as well as its remote sensing by satellites (Arndt et al. 2016; Arndt and Haas 2019). Therefore, we will carry out extensive snow thickness and stratigraphy observations (Arndt and Paul 2018).

The Weddell Sea hosts a diverse ecosystem which significantly relies on sea ice associated carbon production (Vernet et al. 2019). Nearly 50 % of the annual Antarctic sea ice primary production (15.8 Tg C) is produced in the Weddell Sea, in particular its eastern margin is one of the most productive regions (Arrigo et al. 1998). In this region, we witness so-called surface biota communities, which result from flooding and internal snowmelt processes. One consequence of downward heat flux and snow thaw is the percolation of melt water to the snow-ice interface and the formation of gap layers, continuous or highly porous layers in the upper ice filled with seawater or slush and high concentrations of algae and other micro-organisms (e.g. Haas et al. 2001; Kattner et al. 2004). In these habitats, we find a strong accumulation of organic compounds (e.g. Papadimitriou et al. 2009). Nevertheless, due to the patchy distribution of the sea-ice biota both horizontally and vertically, it is still difficult to obtain accurate estimates (Meiners et al. 2012; Meiners 2018). The dissolved and particulate components from the ice can be transferred from the surface to deeper layers and can significantly affect the underlying water column (Laukert et al. 2017). The same is true for gypsum crystals, so far only found in Arctic sea ice (Wollenbrug et al. 2018), which could also be a ballasting factor for *Phaeocystis*, which dominates the gap layers in the Antarctic. In the planned research region of PS124, we expect a widespread occurrence of gap layers, which have rarely been sampled with regard to ice thickness, biodiversity, biomass, dissolved substances, and other biogeochemical processes. The investigations will be complemented by microplastic (MP) analysis in sea ice cores, since sea ice plays a special role in the temporary accumulation and storage of MP particles and their transport to other areas far away from the original source (Peeken et al. 2018), and not much is known yet about this in the Weddell Sea.

Finally, the occurrence of Ice Shelf Water (ISW) contributes strongly to sea ice growth through the formation of platelet ice, provided the ISW emerges from the cavity at the level of the ice shelf base. Platelet ice is also a hot spot of biological production (Günther et al. 1999). While there is an abundance of platelet ice derived from Eastern Shelf Water along the coast of Dronning Maud Land (e.g. Arndt et al. 2020), it is still unclear if there are significant amounts of platelet ice in front of the Filchner-Ronne Ice Shelf. We will therefore survey the fast ice in front of ice shelves to acquire an inventory of platelet ice as an indicator of extensive ISW emergence (Haas et al. 2020) and characterize its role in the biological carbon cycle.

Work at sea

Helicopter-based ice thickness surveys

We will carry out extensive sea ice thickness surveys by means of electromagnetic induction (EM) sounding using an EM Bird. The EM Bird is a towed sensor slung 20 m below the helicopter. Typical profiles will follow triangular flight tracks with a side length of 40 nautical miles, i.e. 120 nm in total (1.5 hrs). We plan to carry out as many surveys as possible, over as many different ice regimes as can be identified by satellite radar imagery.

Snow and ice sampling

We will visit individual ice floes by means of helicopters to sample the properties of snow, surface ice, and gap water. Doing so, the following measurements and sampling will be carried out:

- Snow pit analysis of stratigraphy and density, salinity, etc.
- Snow micro-penetrometer profiles of ice hardness, density, and stratigraphy.
- IceCube measurements of snow-specific surface area
- Ground-EM measurements of ice thickness
- Surface cores of snow, superimposed ice, and gap layer system
- Water and biological and biogeochemical sampling of sea ice, the gap layer, and under ice environment
- Collection of ice samples for gypsum, isotopes of rare earth elements, and microplastic analysis

Ice-tethered platforms (buoys)

A set of autonomous ice tethered platforms (buoys) will be deployed to monitor the seasonal and inter-annual variability of sea-ice parameters, such as sea-ice drift and deformation as well as snow depth variations. While Snow Buoys (measuring snow accumulation) will be deployed spread over the ice-covered survey area, Surface Velocity Profiler (measuring oceanic and sea-ice drift) will be deployed in clusters of 3 to 5 buoys to determine sea-ice deformation processes and rates.

On board

- Routine ice observations from the ship's bridge
- Processing and analysis of snow, ice, and biological and biogeochemical samples, including ice texture analysis.
- Reception and analysis of satellite data, including scientific use of FramSAT system and IceViewer.

Preliminary (expected) results

Overall, results of the sea-ice program shall lead to a better understanding of the sea-ice thickness, properties, and drift in the study area in order to unravel the causes of increased summer ice extent and the special role of the Weddell Sea's sea ice cover in Antarctica. Therefore, our expected results can be summarized as following:

- Observations of the thickness distribution of different ice regimes in the southern Weddell Sea in relation to their deformational history and oceanic heat regimes.
- Comparison of ice thickness results with previous results from the same region (PS111 cruise) to observe long-term ice thickness changes.
- Observations of snow properties and the degree of snow metamorphism to evaluate the intensity of snow melt during the preceding, 2020/21 summer, and for improvement and validation of radar and passive microwave remote sensing retrieval algorithms.
- Observations of thickness of superimposed ice and gap layers in relation to the observed intensity of snow metamorphism and melt.
- Understanding the variability and biodiversity of the sea ice associated biomass with respect to the sea ice and gap layer condition.
- Study the role of gap layers for the seeding of water column blooms
- Assess the role of sea-ice biota for the cryo-pelagic, cryo-benthic coupling
- Observations of biogeochemical properties, gypsum, isotopes of rare earth elements, and microplastics in the southerrn Weddell Sea.

Data management

Scientific data will be submitted to PANGAEA (www.pangaea.de) upon publication as soon as the data is available and quality-assessed. We expect all data to be available within a maximum of two years after completion of the expedition. Buoy data will be available in near-real time through the online portal www.meereisportal.de, and will be embedded into different international data bases, as through the International Program for Antarctic Buoys (IPAB).

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6. EFFECTS OF CLIMATE CHANGE-INDUCED PHYTOPLANKTON COMMUNITY SHIFTS AND WATER MASS DRIVEN PARTICLE TRANSPORT ON SOUTHERN OCEAN CARBON CYCLING

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Grant No. AWI_PS124_13

Objectives

Climatic changes in the Southern Ocean bear important implications for the global marine carbon cycle. This includes shifts in phytoplankton productivity and community structure as well as oceanographic phenomena such as currents and cross-shelf transport.

The strength of the biological carbon pump depends on the functional types of phytoplankton present, which act as vectors for vertical carbon export. While the flagellate *Phaeocystis* *antarctica* is considered to be insignificant for vertical transport of biogenic matter, diatoms can significantly affect carbon export depending on the degree of silicification of their frustules and hence, the velocity with which they settle out of the biologically active zone (Iversen and Plough 2010). Previous studies have reported a possible shift in phytoplankton community structure from diatoms to small flagellates such as *Phaeocystis* spp. over the last decade due to climate change effects (e.g., Trimborn et al. 2016), with unknown consequences for nutrient and carbon cycling.

Currents also play an important role for carbon sequestration due to their ability to inject particles into deeper layers. In the Southern Ocean, High Salinity Shelf Water (HSSW, e.g. Jacobs et al. 1985) is of special interest, because it flows along the sea floor where it potentially re-suspends organic material and transports it across the continental slope towards the deep sea. A similar process was recently observed in the Arctic Ocean where propagating dense Barents Sea bottom water caused a widespread particle plume at ~1,000 m in the Eurasian Basin (Rogge et al. in prep.).

To assess the potential for future biological CO_2 sequestration in the Southern Ocean, we will conduct aggregate formation experiments to test taxon-specific aggregation capacities in the presence and absence of grazing copepods. These experiments will be accompanied by *in-situ* observations of export flux and particle characteristics in regions with shifting phytoplankton assemblages.

Work at sea

To assess particle dynamics in the water column, we will perform deployments of an Underwater Vision Profiler camera system (UVP) in combination with drifting sediment traps. The UVP is a high frequency (20Hz) particle quantification and imaging system mounted on the CTD rosette. The UVP automatically recognizes and counts particles >100 µm and stores images of particles >1mm. This allows high-resolution particle profiles (acquisition every 5 cm with 1m s^{-1} winch speed) for every CTD cast in parallel to water mass property measurements due to its 6000-m depth rating.

Drifting sediment traps will be deployed at up to 15 stations. A drifting sediment trap consists of three trap stations (usually at depths of 100, 200 and 400 m), each equipped with four collection cylinders. At every trap depth, one of the collection cylinders is filled with a viscous gel to structurally preserve fragile marine snow aggregates and fecal pellets and determine their abundance and size spectra. Each drifting sediment trap is deployed for 24 h to capture the day-night cycle of carbon flux in the study area.

Marine snow catchers will be deployed to sample marine aggregates at about 10-20 m below the peak of the chlorophyll maximum (as seen from the CTD chlorophyll sensors). After deployment, aggregates collected in the 100-L volume will be left to settle to the base of the MSC on deck for 3-10 h. Individual aggregates are gently collected using a wide-mouth bore pipette and transferred to a flow chamber system equipped with an O_2 microsensor for onboard measurements of aggregate size, sinking velocity and microbial respiration (see Ploug and Jørgensen 1999).

The characterization of *in-situ* collected aggregates will be accompanied by aggregate formation experiments in the laboratory. The phytoplankton assemblage found *in-situ* (as sampled from the CTD rosette) will be manipulated through size fractionation, and aggregates formed from the respective assemblages will be characterized comprehensively in the flow chamber system.

Expected results

Expected results will provide estimates on the change in carbon export efficiency of the Southern Ocean induced by climate change, including insights into the resilience of the Southern Ocean towards an increase in atmospheric CO_2.

The vertical particle concentrations and size distribution determined with the UVP camera system in combination with the drifting sediment traps will yield high-resolution carbon flux measurements and remineralisation rates across the water column.

The characterization of aggregates formed in the present vs. future Southern Ocean (extrapolated from our on-board manipulation experiments) will yield insight into the change in aggregation capacity, settling velocity, carbon content, and carbon export efficiency between present and future phytoplankton assemblages.

Together, the *in-situ* and on-board studies will provide a detailed full water column perspective on the export of organic matter as a function of varying phytoplankton assemblages, grazing by zooplankton, and a possible inflow of particles by lateral transport. These studies are essential to understanding the impact of community shifts and deep particle injection on the biological pump and, thus, its role in providing nutrients to pelagic and benthic ecosystems as well as carbon export to the Antarctic seafloor.

Data management

Environmental data collected during the expedition will be stored in the Open access library PANGAEA (Data Publisher for Earth & Environmental Science, www.pangaea.de), hosted by AWI and MARUM and published within two years after the end of the cruise.

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ).

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

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7. BIOGEOCHEMICAL CYCLING IN THE SOUTHERN WEDDELL SEA

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Grant No. AWI_PS124_01

Outline

The southern Weddell Sea continental shelf is an area of intense sea-ice and bottom water formation, which coincides with a high, patchily distributed primary production, most likely sequestering CO_2 at significant rates. According to recent IPCC-scenario simulations, the southeastern Weddell Sea is extremely sensitive to climate change, causing transformations of water mass characteristics, ocean circulation, and biological production. Many regions of the Southern Ocean are regions were primary production is controlled by the availability of trace nutrients, primarily iron, and it has been demonstrated that the addition of trace metals (TM) and vitamin B_{12} can enhance plankton biomass and/or change the community composition (Balaguer et al. in prep; Koch et al. 2011). To date, dissolved TM concentrations have only been published for the northern most Weddell Sea (Klunder et al. 2011, 2014) and revealed very low (<0.2 nM, Fig. 7.1) and potentially biomass limiting iron and manganese concentrations at the surface, while concentrations of the essential vitamin B_{12} has never been measured. Cycling of TMs, including grazing mediated recycling rates are also unknown. For the Southern Ocean in particular, phytoplankton productivity and community structure bear important implications for the global marine carbon cycle. Indeed, the strength of the biological carbon pump depends on the functional types of phytoplankton present, since each group will contribute differentially to vertical carbon export. While the flagellate *Phaeocystis antarctica* is considered to be insignificant for vertical transport of biogenic matter, diatoms can significantly affect carbon export. Over the last decade, studies have reported a shift in phytoplankton community structure from diatoms to small flagellates, such as *Phaeocystis* sp., due to elevated temperatures and ice-melting with unknown consequences for nutrient and carbon cycling (Heiden et al. 2019). The impacts of different iron sources and trace nutrients such as manganese and vitamin B_{12}, and physical changes such as altered light availability on the plankton community composition in the Weddell Sea, however, have never been investigated.

As part of the overall goal of PS124 we aim to:

- characterize the biochemistry of the water masses, focusing on the key players in the plankton community responsible for primary and secondary production,
- assess primary and bacterial production rates in the euphotic zone,
- measure concentrations and cycling (uptake, recycling) of trace metals and vitamins,
- conduct nutrient amendment and grazing manipulation experiments in order to identify key bottom up and top down processes driving the biological pump and thus carbon export.

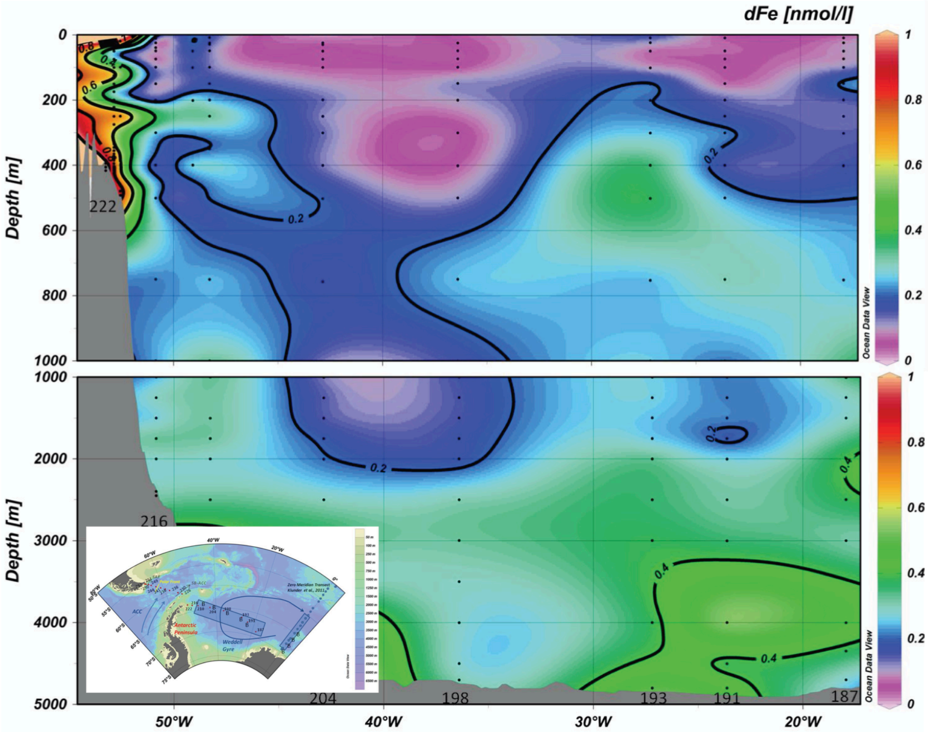

Fig. 7.1: Distribution of dissolved iron across the northern Weddell Sea. Adapted from Klunder et al. (2014).

Work at sea

In order to characterize the water chemistry and the plankton community, water will be sampled at 25 stations. In addition, at up to 6 contrasting stations, water will be sampled with a TM clean Teflon pump and used for targeted bottle manipulation experiments looking at grazing, the effects of TMs/vitamins and varying light regimes. Depth integrated primary- and bacterial production rates will also be assessed at 15 stations. More specifically:

(1) At 25 stations and 6 depths water will be collected with the AWIs new, state of the art, trace metal clean sampling infrastructure including a Teflon CTD equipped with GoFlo bottles (12L/bottle capacity). Samples for microscopy, flowcytomtery, molecular analysis and pigments will be taken along with particulate organic carbon, biogenic silica, and analyzed back at the AWI. Water will be filtered and frozen or acidified for later trace metal and nutrient analysis at the AWI.

(2) At 15 stations and three depths, ^{14}C-bicarbonate and ^{3}H-leucine will be used to measure size fractionated (0.2-2, 2-20 and >20 μm) primary- and total bacterial production rates, respectively. Also surface uptake rates of iron and B_{12} will be measured using ^{55}Fe and ^{57}Co-B_{12}. Cycling of iron and B_{12} will also be assessed.

(3) At 6 stations, seawater will be pumped on board with the help of a Teflon membrane pump. For this, a LDPE Hose will be lowered to 25 m and ~1,500 L seawater will be pumped directly into a trace metal clean container where bottles and tanks will be filled for the various experiments. Treatments will include the addition of trace nutrients, melted sea ice, pore water from multicore samples (cooperation with S. Henkel), different light levels, dilution/concentration of various grazers (cooperation with M. Iverson). All bottles will be incubated in climate controlled laboratories or deck-board incubators.

Expected results

In combination with data from S. Henkel's group (see chapter 8), this will be the first data set to characterize the biogeochemistry of the southern Weddell Sea. Our study will provide vertical profiles of TMs in a biologically active area and elucidate their vertical distribution and possible sources. Rate measurements of primary and secondary production, coupled to uptake and recycling rates of TMs and vitamins will shed light on the cycling and dynamics between these essential trace nutrients and the pelagic plankton community. In addition, targeted experiments, in which natural plankton communities are exposed to various TM sources (from sea ice, glaciers, pore water), various co-limiting nutrients (manganese, B_{12}) and light regimes (high/low) will highlight possible shifts in the plankton community due to the climatic changes expected in the coming decades.

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Centre PANGAEA Data Publisher for Earth & Environmental Science (www.pangaea.de) within two years after the end of the cruise at the latest. By default the CC-BY license will be applied.

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ).

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

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8. GEOCHEMISTRY

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Grant No. AWI_PS124_07

Objectives

Antarctic polynyas are characterized by high primary productivity, and it was suggested that this is due to nearby sources of iron (Arrigo et al. 2015). Primary productivity is regulated by iron supplies in large parts of the Southern Ocean (Boyd and Ellwood 2010). Potential sources or iron include melt water deriving from ice shelves and icebergs (Arrigo et al. 2015), sea-ice (Sedwick and DiTullio 1997) and coastal and shelf sediments (Monien et al. 2013; Henkel et al. 2018). Climate change is expected to increase iron discharges via melt waters and continental runoff and thus stimulate primary productivity on Antarctic continental shelves (Raiswell et al. 2008). Despite the fact that iron plays such an important role for the C-pump in the Southern Ocean, data from remote areas like the Weddell Sea are sparse. Only two previous cruises to the Antarctic continental shelf focused on gaining iron data and assessing respective fluxes (Klunder et al. 2011; 2014). One of the main areas for potential iron supply, the southern Weddell Sea shelf, is basically an uncharted area in terms of geochemistry. Several perceivable pathways of iron for the Weddell Gyre could thus not be tested so far, namely sedimentary shelf inputs, basal melting of glaciers, "dirty" sea ice, or subglacial lake discharge. The very first samples of potential iron sources became available during PS111 (Schröder 2018), allowing now to estimate the potential of the tracers, but are so far not associated with a sufficient number of water column Fe data to quantify iron fluxes. Geochemical tracers such as Fe isotopes ($\delta^{56}Fe$) will be used to separate different nutrient sources and assess their relative importance. The potential of an integrated approach including physical oceanography, biology, geochemical tracer studies, and biogeochemistry has been demonstrated for the eastern Weddell Gyre (Geibert et al. 2010) and is applied here to new areas.

Silicon (Si) isotopes ($\delta^{30}Si$) are applied as tracers to investigate nutrient utilization by diatoms in the surface waters (De La Rocha et al. 2000), but can also provide information about dissolution of particles in the water column as well as water mass mixing of intermediate and deep waters (de Souza et al. 2012; Liguori et al. 2020). Fe is a major limiting factor for diatom growth in the Southern Ocean, and fertilization by Fe affects nutrient (Si:N) uptake ratios by diatoms (Brzezinski et al. 2003). Furthermore, Pichevin et al. (2014) have shown that bSi burial might strongly be affected by Fe availability, a process with great implications for paleoceanographic studies.

Si isotopes were introduced recently as tracers for early diagenetic processes in sediments like dissolution of diatoms as well as the neoformation of authigenic silicate phases (Ehlert et al. 2016), a process with potential implications for global trace metal cycling (e.g., Michalopoulos and Aller 2004).

In this key-area of deep and bottom water formation, the end-member composition of water masses is also of vital importance for the use of paleo-oceanographic tracers such as neodymium isotopes (expressed in εNd) which are used to investigate past ocean circulation patterns (Frank 2002). Previous studies suggest a modification of εNd in AABW during its formation by exchange processes with the continental shelf (Carter et al. 2012; Stichel et al., 2012a, 2012b). Thus, there is a need to assess the modification of source waters when they enter the Filchner or Central Trough, which are located in different geological settings. The source regions of the ice streams feeding FRIS also are of distinct geologies (Dalziel 1992). Characterizing the impact of the ice sheet on the Nd isotopic composition of AABW is crucial for paleo-oceanographic reconstructions.

Our general objective is to quantify the Antarctic continental shelf's contribution to global nutrient/iron budgets.

More specifically, our work on board includes the following objectives:

- Characterization of water masses on the southern Weddell Sea continental shelf and determination of glacial melt water contents and nutrient concentrations.
- Determination of fluxes of macro- and micronutrients from shelf and slope sediments to the water column and its potential to fertilize the high nutrient low chlorophyll (HNLC) Weddell Sea.
- Assessment of the contribution of early diagenetic processes to the recycling of nutrients and benthic fluxes.

Work at sea

Water Column

At 15-20 stations, we will sample water from CTD-Rosette deployments for radionuclides (Ra/Th), neodymium isotopes (εNd), rare earth elements (REE), and silicon isotopes. At 8 "super-stations", sampling is complemented by collection of water and, if feasible, suspended matter for iron isotope analysis. For such sampling, water from Teflon-CTD-Rosette deployments will be filtered under trace metal clean conditions. In addition, we will collect complementary 1L subsamples for radiocarbon ($\Delta^{14}C$) analysis of dissolved organic matter (DOC). This small pilot study aims to test the applicability of $DO^{14}C$ as tracer for fresh organic matter produced in the polynya and its subsequent export during deep water formation. Sampling procedures will largely comply with the GEOTRACES guidelines (www.geotraces.org).

Sediment

At up to 25 stations, MUC cores will be sampled for pore water and sediment analyses. Pore water will be extracted by use of rhizons (Seeberg-Elverfeldt et al. 2005). Dissolved iron (Fe^{2+}) will be measured onboard spectrophotometrically. Subsamples for all other pore water analyses (NO_3^-, NO_2^-, PO_4^{3-}, SO_4^{2-}, DIC, NH_4^+, H_2S, $SiOH_4$, $\delta^{30}Si$ and cations) will be conserved and stored for measurement at AWI.

Sediment samples will be taken for geochemical characterization such as bulk element composition. Further, geochemical tracers of sediment origin, reactive Fe and Si phases and ^{210}Pb will be determined on selected stations. ^{210}Pb serves as bioturbation indicator and will be used to calculate accumulation rates. The Nd isotopic composition and REE distribution in surface sediments will assist to characterize the terrigenous supply of external εNd in shaping the water mass composition.

Preliminary (expected) results

The samples taken during PS124 will improve the data availability for trace metal concentrations in the Weddell Sea and improve our understanding of nutrient and, in particular, iron and Si fluxes in this remote area. With such data we expect to be able to draw conclusions about the relative importance of different nutrient sources (e.g. benthic release from shelf sediments vs. melting of shelf and marine ice). The detailed investigation of radiogenic isotopes (Nd) and REE of contributing water masses to AABW will be of great value for palaeoceanographic reconstructions.

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Centre PANGAEA Data Publisher for Earth & Environmental Science (www.pangaea.de) within two years after the end of the cruise at the latest. By default the CC-BY license will be applied.

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ).

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

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9. BENTHIC FAUNA

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Objectives

The high primary production on Antarctic continental shelves supports a thriving pelagic ecosystem (Arrigo et al. 2015). A considerable fraction of organic carbon sinks out of the mixed layer and eventually reaches the seafloor, where it is assumed to sustain a rich, well adapted benthic fauna (Arntz et al. 1994). So far, estimates for this biological carbon pump are missing for the WS shelf. Reliable values are needed, however, in order to establish a reliable budget for the Southern Ocean. It is important to establish an early reference, as climate change is expected to significantly change sea-ice cover, primary production, benthic fluxes and benthic fauna, and carbon storage on the Antarctic continental shelves (Pineda-Metz et al. 2020). The seafloor provides an integrated signal of the downward carbon flux and reflects the efficiency of the biological carbon pump. Benthic oxygen uptake provides an integrated measurement of benthic mineralization and is crucial for balancing the benthic carbon cycle. So far, benthic fauna studies in this region did not include oxygen flux measurements so that the receiving carbon flux remains largely unknown, as well as the return flux of essential nutrients to the water column. In addition, the response of benthic fauna biomass changes to organic carbon supply needs a better understanding to evaluate the expected change in primary production and its effect on blue carbon storage. The WS continental shelf harbours unique benthic communities dominated by suspension feeders, which are often structured by sponges (Federwisch et al. 2020). Despite a good documentation of benthic community types and composition, little is known about community dynamics. Repeat observations in the western WS suggest that growth of benthic fauna can be significantly higher than previously assumed, most likely due to the changed carbon supply (Fillinger et al. 2013). So far, repeat observations to detect benthic community change and megafauna growth are scarce at these latitudes, and oxygen flux measurements are entirely lacking. In recent years, autonomous measuring systems have been developed to determine *in-situ* oxygen fluxes and mass transport across the bentho-pelagic interface. This includes stationary Landers, which allow quantifying the integrated benthic oxygen uptake of large areas (10-100 m^2), i.e., on ecosystem level (Holtappels et al. 2015), where the analysis of seawater properties has been automated and miniaturized so that “Lab-on-Chip” sensors are now able to record temporal changes of, e.g., nitrate concentrations in seawater (Beaton et al. 2012). The automation of environmental measurements and its use in marine research is of utmost importance especially for polar regions where most of the data has been collected in summer and little is known throughout the rest of the year.

General objectives:

- Specify the environmental and biological controls on the distribution of the macro- and mega-benthos community structure and function on the southern Weddell Sea continental shelf.
- Determine the spatial variability of the macro- and mega-benthic community structure and function on the shelf, in the Filchner Trough and continental shelf break with regard to water mass distribution (Ice Shelf Water outflow, Antarctic Bottom Water formation, Modified Warm Deep Water onshore flow) and sea-ice cover.
- Identify temporal trends by repeating sampling stations occupied in earlier expeditions.
- Provide a comprehensive dataset to link biota to environmental data for numerical modelling.
- Establish a TCO2/POC/DOC inventory of major water masses on the southern shelf to estimate C export by deep water formation.
- Identify regions with contrasting TCO2 drawdown due to highly variable primary production and nutrient dynamics.

Specific objectives:

- Determine the abundance, biomass, and diversity of benthic fauna on the shelf and at the shelf break in relation to organic carbon availability, seafloor substrate, and bottom current regime.

- Determine benthic mineralization and turnover by measuring the diffusive and total benthic oxygen uptake at sites with contrasting primary production.
- Determine biodiversity of sea spiders, an abundant component of the Antarctic continental shelf benthic macrofauna (Griffiths et al. 2011), in the study area.
- Preserve adults and postlarval instars of selected sea spider taxa for subsequent neuroanatomical and developmental investigations.
- Determine seawater dissolved inorganic carbon (DIC), total alkalinity (TA), particulate carbon and nitrogen (POC/N), and chlorophyll *a* (Chl *a*), which are important geochemical drivers of biological processes (e.g. calcification) and carbon export.

The combination of data on benthic structure and function over a wide size-range combined with repeated sampling of stations visited in previous expeditions aims at describing the benthic community structure and function in the present physico-chemical environment in the southern Weddell Sea, and to monitor its variability and trends. If ice conditions permit access to the area west of the Filchner Trough, we will be able to sample areas which have never been sampled before.

As an add-on, a mooring will be deployed at Maud Rise (66° S) north of the main study area at the end of the expedition to investigate the temporal dynamics of phytoplankton growth, nutrient/CO_2 concentrations, export production, and sedimentation in this dynamic area which occasionally features a large polynya.

Work at sea

Megafauna (H. Schröder, S.E.A. Pineda-Metz): Megafauna will be assessed in cooperation with the Deep-Sea Ecology group using non-invasive image analyses of the video material collected with the OFOBS (see chapter 9).

Macrofauna (S.E.A. Pineda-Metz, G. Brenneis): Macrofauna will be collected with the Multiple Grab (MG) which allows parallel sampling of up to 8 box-cores for adequate coverage. Samples will be sieved over 1,000 and 500 µm mesh. Two cores will be conserved in 96 % ethanol for qualitative systematic and molecular genetic analyses and voucher specimens. Six sieved core samples will be preserved in borax-buffered 10 % formalin (i.e. 4 % formaldehyde) to assess densities, biomass, composition, and distribution patterns of macrofauna.

Sea spiders (G. Brenneis): Specimens of sea spider taxa with a distribution center in the Southern Ocean (Munilla and Soler Membrives 2009) will be picked from MG samples prior to bulk preservation. Animals intended for immunohistochemical study will be fixed for 24 h in 4 % paraformaldehyde (PFA) or a combination of 4 % (m/v) EDAC + 4 % PFA (both in filtered seawater) and transferred into cryoprotectant buffer (sodium phosphate buffer w/ sucrose, ethylene glycol and polyvinylpyrrolidone) for storage at -20°C. Specimens intended for histological study and micro-computed tomography will be placed in Bouin's solution or alcoholic-acetic-formalin fixative with subsequent transfer into 70 % ethanol. Preceding fixation, single legs will be removed with surgical micro-scissors and placed in 100 % ethanol for DNA barcoding to confirm species identification.

Benthic Lander (M. Holtappels, H. Schröder): An autonomous benthic lander will be used to determine benthic oxygen consumption and nutrient fluxes across the sediment-water interface. It will be equipped with Eddy Covariance devices for non-invasive turbulent flux measurements. It will be deployed as a moored system with additional CTD and current profilers attached throughout the water column and bear a pop-up buoy as a back-up to be able to retrieve the lander in case it is needed. It should be noted that during PS124 two other landers will be deployed (see chapter 9) equipped with benthic chambers and microprofilers.

Lab-on-Chip sensors (A. Schaap): Lab-on-Chip (LoC) devices allow for automated *in-situ* measurements of nutrients, DIC, TA, and pH. For the latter three parameters, a new LoC device is still under development but should be deployable in 2021. It is planned to use LoC for short term deployments on Benthic Landers. These are classical wet chemical analyses on a microfluidic chip. Only minimal amounts of reagents (less than one ml) are required for a measurement. The required reagents are packed in solid plastic bags (Flexboy) and all liquid waste is also collected in these bags.

TCO2, TA, DOC, POC/N, Chl a (A. Dürwald, T. Hargesheimer): 250 ml seawater for TCO2 and TA will be taken from CTD-Rosette, fixed with $HgCl_2$ and stored for analysis at AWI. 2L-Seawater samples will be taken from CTD-Rosette, filtered through pre-combusted GF/F filtersand stored frozen until analysis for particulate carbon and nitrogen. 2L seawater samples will be filtered through GF/F filters. Filters will be frozen for Chl *a* analyses and aliquots of the filtrate frozen for nutrient analyses. 2L seawater samples will be filtered, acidified and stored at 4°C until DOC analysis.

Biogeochemical Mooring (M. Holtappels, H. Schröder, T. Hargesheimer): In order to study the open water polynya at Maud Rise and its effect on temporal dynamics of phytoplankton growth, nutrient/CO2 concentrations, export production and sedimentation, a mooring will be deployed at Maud Rise (approx. 66°S, 0°) at the end of the expedition. The mooring will consist of: remote access sampler (RAS) to sample 0.5L volumes of seawater every 1-2 weeks, 2 nitrate sensors, pCO2 sensor, Fluorescence sensor, pH and TA Lab-on-Chip sensors, Underwater Vision Profiler and CTD-O2, and 2 sediment traps. It is planned to recover the mooring in the following austral summer season.

Preliminary (expected) results

While the oceanographic, sea-ice and pelagic work will provide snapshots of the instantaneous environmental conditions in the research area, the benthic perspective offered by our group provides an integrated view of the temporally averaged conditions, reflected in the benthic community composition and biogeochemical properties in the sediments, both affecting the mass fluxes measured by the eddy lander. The interpretation of the complementary projects contributing to COSMUS will provide a high level of synergies so that the overall result will be much larger than the sum of its parts. For the benthic part in particular, we expect to be able to quantify for the first time the carbon and nutrient budgets for the Weddell Sea continental shelf, and assess the benthic response to important spatio-temporal changes in sea-ice cover and productivity. The results will be highly relevant to the new Helmholtz Research Programme “Changing Earth – Sustaining our Future” Subtopics 2.1 (Warming climates), 4.1 (Fluxes and transformations of energy and matter in and across compartments), 6.1 (Future ecosystem functionality) and 6.3 (The future biological pump).

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (www.pangaea.de) within two years after the end of the cruise at the latest. By default the CC-BY license will be applied.

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ).

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

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10. BENTHIC FLUXES AND HABITATS

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Grant No. AWI_PS124_02

Objectives

Benthic communities are strictly dependent on carbon supply through the water column, which is determined by temporal and spatial variations in the vertical export flux from the euphotic zone but also lateral supply from shelf areas. Most organic carbon is recycled in the pelagic, but a significant fraction of the organic material ultimately reaches the seafloor, where it is either re-mineralized or retained in the sediment record. One of the central questions is to what extent sea-ice cover controls primary production and subsequent export of carbon to the seafloor on a seasonal and interannual scale. Benthic oxygen fluxes provide the best and integrated measurement of the metabolic activity of surface sediments. They quantify benthic carbon mineralization rates and thus can be used to evaluate the efficiency of the biological pump.

Seafloor habitats and associated benthic fauna will be investigated with the Ocean Floor Observation and Bathymetry System (OFOBS). OFOBS is a towed device capable of deployment in moderately ice-covered regions and capable of concurrently collecting acoustic as well as video and still image data from the seafloor (Purser et al. 2018). These data will serve two purposes: (1) habitat mapping, and (2) macroecological studies of megabenthic biodiversity patterns. Habitat mapping OFOBS data streams will be integrated to produce high-resolution 3D spatial models (topographic maps) of the seafloor. These models will allow subsequent high-resolution analysis of terrain variables, such as slope, aspect and rugosity, and their relationship to the distribution of benthic fauna on a finer scale than has previously been possible in the Weddell Sea. Moreover, OFOBS-derived information will support the work of the other biologist / ecologist cruise participants and onshore collaborators. Macroecological studies OFOBS images will be surveyed for the composition, diversity, and distribution of megabenthic assemblages. Megabenthic fauna are of very high ecological significance for the Antarctic shelf ecosystems. They strongly affect the small-scale topography of seafloor habitats and do, thus, exert prime influence on the structure of the entire benthic community.

Work at sea

Benthic fluxes

Seafloor carbon mineralization will be studied *in-situ* using a benthic lander system (Hoffmann et al. 2018). The benthic O2 uptake is a commonly used measure for the total benthic mineralization rate. We plan to measure benthic oxygen consumption rates at different spatial and temporal scales.

A benthic lander will be equipped with two different instruments to investigate the oxygen penetration and distribution as well as the oxygen uptake of Antarctic deep-sea sediments: (1) microprofiler, for high-resolution pore water profiles (O2, T, resistivity), and (2) a benthic chamber, to measure the total oxygen consumption and nutrient exchange of the sediment. The overall benthic reaction is followed by measurement of sediment community oxygen consumption to calculate carbon turnover rates. From the sediments recovered by the benthic chambers, we will take subsamples to quantify the organic carbon content, microbial communities, and sieve out the larger macrofauna.

Habitat mapping

OFOBS is a cabled/towed system deployed ~1.5 m above the seafloor at very low ship speeds of max. 0.5 knots (for more detailed information see Purser et al. (2018)). While in operation, the exact location of the georeferenced system is determined and verified continuously by *Polarstern*'s POSIDONIA system, and refined by the new integrated Inertial Navigation System (INS) and Dynamic Velocity Logger (DVL).

In addition to collecting image data comparable with those collected from the region and surrounding areas by preceding survey cruises, OFOBS will also collect in parallel high-resolution topographical information from the seafloor by using a sidescan sonar system and a forward-facing acoustic camera. The sidescan system allows a ~100 m swath of seafloor to be investigated acoustically at the same time as the collection of still and video camera images. During recent cruises the facility for this combined system to generate useful data on geological structure distribution, high-resolution topographical products and faunal distribution maps has been demonstrated.

Preliminary (expected) results

The overall aim of the lander deployments is to cover the spatial variation in settling organic matter on the seafloor with contrasting and changing food supplies and to resolve the impact on the benthic community respiration activity. From the *in-situ* measurements we expect new insights in the benthic oxygen consumption rates in this area. The collection of images and acoustic topographical high-resolution data of seafloor is envisaged which will improve our understanding of habitat distributions in the Weddell Sea. The use of new underwater technologies will thereby enhance our capabilities to improve our knowledge on the effects of climate change on the Antarctic ecosystem.

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Centre PANGAEA Data Publisher for Earth & Environmental Science (www.pangaea.de) within two years after the end of the cruise at the latest. By default the CC-BY license will be applied.

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ).

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11. OCCURRENCE OF MICROPLASTICS IN THE SOUTHERN OCEAN

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Grant No. AWI_PS124_10

Objectives

Our aim is to study the occurrence, concentration, distribution and, eventually, the possible sources of microplastics (MP) in the Antarctic marine ecosystem. We aim to achieve the following results by:

(1) Sampling and analyzing surface- and sub-surface water of the Southern Ocean.
(2) Characterizing the MP in the Southern Ocean with respect to particle size, morphology, polymer types and color to ascertain origins and possible (former) uses.
(3) Assessing the characteristics, concentration and distribution of MP in the relatively pristine Weddell Sea (WS) compared to the more anthropogenically-impacted Scotia Sea (SS) and Western Antarctic Peninsula (WAP)

(4) In case our German colleague (H. Bornemann, SEAROSE, chapter 3) can successfully sample seal faeces, we will analyze these faeces, aiming at assessing the amount of MP in exemplary marine mammal predator faeces to gain insight on the importance of MP in the Antarctic food web.

(5)

Work at sea

Water will be sampled by filtering the water column via pumping seawater from the surface and from beneath the vessel with (i) the seawater pump of *Polarstern*, Klaus Union Sealex Centrifugal Pump and (ii) a mobile seawater pump (HOMA, CH432). The water retrieved by the Klaus pump will be filtered continuously onto 20 μm stainless steel meshes and replaced every twelve hours. The meshes will be stored frozen for later polymer analysis in the laboratory. The water sampled by the mobile pump will be collected first in a 1,000-l tank and then filtered, as described for the water sampled by the Klaus pump.

Need of rubber boat (standard on-board equipment): In case, we can make use of the rubber boat, e.g., when it is used to deploy or retrieve buoys, drifters or other devices, we would like to make use to deploy a small Manta trawl for 30 minutes. The procedure would be similar to the deployment we conducted in former cruises from board of *Polarstern* (Mani et al. 2018), but instead of deployment from a crane, the trawl will be deployed directly from the rubber boat.

Suspected microplastic particles from the water samples (particles larger than 300 μm) will be prepared and analyzed by a mobile FTIR on board. Smaller particles, suspected to be microplastic, will be prepared for storage (filtered, cleaned, dried and frozen, respectively, and transported back to our laboratory in Switzerland for further analysis on micro FTIR or RAMAN.

We will be provided with seal faeces; sampling of this material is proposed by H. Bornemann's project 'SEAROSE'. This material will be prepared for storage (filtered, cleaned, dried and frozen, respectively, and transported back to our laboratory in Switzerland for further analysis on micro FTIR or RAMAN.

Preliminary (expected) results

We expect to perform 10 to 20 spot samplings with the mobile surface water pump, each resulting in 1 m^3 of filtered seawater. In addition, samples will have been taken from pumped seawater intake in the on-board wet lab. The water sampled by both types of pumps will have been filtered through a stack of geological sieves (a 20 µm sieve (combined with 100 µm and 300 µm sieves). Samples will have been sealed with metal lids, labelled by the lowest applied mesh size and stored in v:v 50:50 suspended sample: EtoH at 4° C. Quality control and contamination protection is a crucial aspect and we will tackle this issue very seriously, applying all precautionary measures as described by Mani et al. (2018).

We also attempt to prepare the samples (rinsing, cleaning, removing of organic material - such as plankton and debris - by enzymatic digestion) and transfer them into a Bogorov counting chamber for visual inspection using a stereomicroscope (Olympus SZ61) equipped with a camera (Olympus SC50) and connected to the imaging software CellSens Entry. Putative anthropogenic particles will be sorted, characterized microscopically and photographs will be taken for ease of retrieval in the home laboratory. Particles which are suspected to be plastic as determined by eye (e.g. based on colour, texture and shape; cf. Mani and Burkhardt-Holm, 2020), will be analysed using FT–IR on board.

Data management

Microplastic samples will either be destroyed by analysis or those not analysed will be stored at the home laboratory at University of Basel. Environmental data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (www.pangaea.de) within two years after the end of the cruise at the latest. By default the CC-BY license will be applied.

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

References

Mani T, Burkhardt-Holm P, Segner H, Zennegg M, Amaral-Zettler L (2018) Microplastics – A potential threat to the remote and pristine ecosystems of the Antarctic Seas? The Expedition of the Research Vessel "*Polarstern*" to the Antarctic in 2018/19 (PS117). Berichte zur Polar- und Meeresforschung.

Mani T, Burkhardt-Holm P (2019) Seasonal microplastics variation in nival and pluvial stretches of the Rhine River – From the Swiss catchment towards the North Sea. Science of the Total Environment 707, 135579.

12. TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

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13. FAHRTTEILNEHMER / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
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Name/ Last name	**Vorname/ First name**	**Institut/ Institute**	**Beruf/ Profession**	**Fachrichtung/ Discipline**
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Zillgen	Carsten	DE.HeliService	Pilot	Aviation
Rückkehrer von Neumayer III / Return staff from Neumayer III (NM III)				
Ackle	Roman	DE.RFL	Engineer	Wintering team (WT)
Bähler	Stefanie	DE.RFL	Engineer	Technics NM III
Beyer	Mario	DE.RFL	Engineer	Wintering team
De Almeida Santos	Wanderson	DE.RFL	Cook	Wintering team
Eder	Pitt	DE.RFL	Technician	Technics NM III
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Geis	Peter	COM.Kässbohrer	Technician	Technics NM III
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Vrakking	Vincent	DE.DLR	Engineer	Summer staff NM III
Wehner	Ina	DE.AWI	Scientist	WT Geophysics
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14. SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
	Schwarze, Stefan	Master
	Grundmann, Uwe	C/Mate
	Kentges, Felix	C/Mate Ladung
	Fischer, Tibor	2nd Mate 2
	Lauber, Felix	2nd Mate 3
	Heuck, Hinnerk Soeren	Chief Eng
	Brose, Thomas Christian Gerhard	2nd. Eng
	Krinfeld, Oleksandr	2nd. Eng 1
	Haack, Michael Detlev	2nd. Eng 2
	Mueller, Andreas	Chief Elec.Eng.1
	Frank, Gerhard	Elec./Eng. Brücke
	Huettebraeucker, Olaf	Elec./Eng. Labor
	Redmer, Jens Dirk	Elec./Eng. SET
	Nasis, Ilias	Elec./Eng. System
	Krueger, Lars	Elec./Eng. Winde
	Brueck, Sebastian	Bosun
	TBN	MP Rating/D 2
	Moeller, Falko	MP Rating/D 3
	Decker, Jens	MP Rating/D 1
	Buchholz, Joscha	MP Rating/D 4
	Klee, Philipp	MP Rating/D 7
	Wende, Uwe	AB 1
	Schwarz, Uwe	MP Rating/M 1
	Gebhardt, Norman	MP Rating/M 2
	Rhau	MP Rating/M 4
	Teichert	MP Rating/M 5
	Sautmann, David	MP Rating/M 3
	Lello, Ants	Carp. 1
	Baecker, Andreas	AB 3
	Burzan, Gerd-Ekkehard	AB 9
	Preußner	Fitter/E 1
	TBN	Cook 1
	Silinski, F.	2nd Cook 1
	Zahn	2nd Cook 2
	Czyborra, Baerbel	C/Stwd. 1
	Braun	Stwd./KS
	Silinski, Carmen Viola	2nd Stwd. 1
	Dibenau, Torsten Karl	2nd Stwd. 2

No.	Name	Rank
	Bachmann, Julia Maria	2nd Stwd. 3
	Arendt, Rene	2nd Stwd. 4
	Sun, Yongsheng	2nd Stwd. 5
	Chen, Danheng	2nd Stwd. 6
	Goessmann - Lange, Petra	Doc. 1
	Stellamanns, Thies Christian	App.MP 1
	Krumrei, Benni	App.MP 2