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

EXPEDITION PROGRAMME PS111

Polarstern

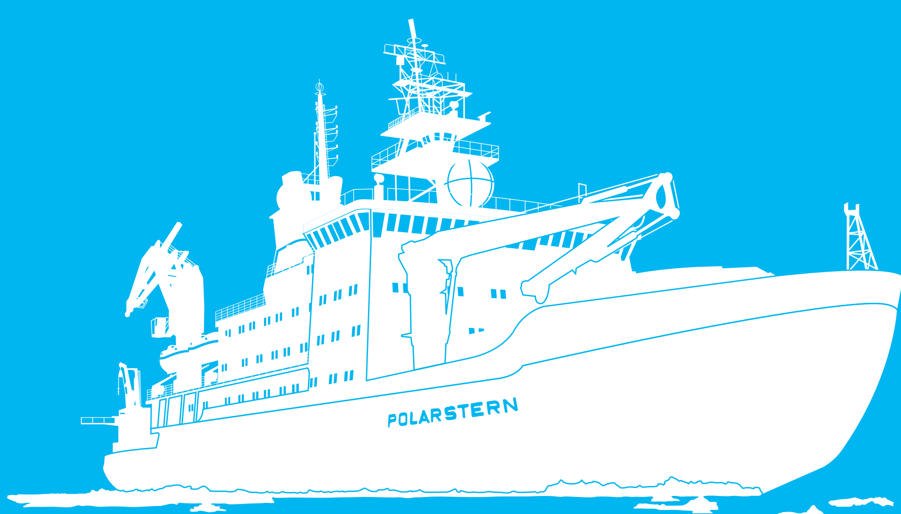
PS111

Cape Town - Punta Arenas

19 January 2018 - 14 March 2018

Coordinator: Rainer Knust

Chief Scientist: Michael Schröder



Bremerhaven, November 2017

Alfred-Wegener-Institut
Helmholtz-Zentrum
für Polar- und Meeresforschung
Am Handelshafen 12
D-27570 Bremerhaven

Telefon: ++49 471 4831- 0
Telefax: ++49 471 4831 – 1149
E-Mail: info@awi.de
Website: http://www.awi.de

Email Coordinator: rainer.knust@awi.de
Email Chief Scientist: michael.schroeder@awi.de

PS111

FROST

Cape Town - Punta Arenas

19 January 2018 - 14 March 2018

FROST: Filchner Ronne Outflow System Tomorrow

Coordinator
Rainer Knust

Chief Scientist
Michael Schröder

Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Michael Schröder (AWI)

Der Fahrtabschnitt PS111 FROST, Filchner Ronne Outflow System Tomorrow, wird am 19. Januar 2018 in Kapstadt (Südafrika) beginnen und am 14. März 2018 in Punta Arenas (Chile) enden. *Polarstern* wird direkt die eisbedeckte Atka-Bucht anlaufen, um die *Neumayer-III-Station* zu versorgen. Bedingt durch eine Vielzahl von Feldkampagnen im Hinterland von *Neumayer* ist das Frachtaufkommen und die Treibstoffmenge maximal, so dass für die Versorgung eine entsprechende Zeit eingerechnet werden muss. An Neumayer gibt es den Austausch einer Person, so dass auch im weiteren Verlauf der Expedition das Schiff voll besetzt ist. Wenn die Eissituation es erlaubt, wird auf dem Weg nach Süden im Bereich des Küstenstroms ein kurzes Messprogramm eingeschoben, was als Teststation für die beteiligten Arbeitsgruppen dienen soll. Danach wird sich *Polarstern* in das eigentliche Forschungsgebiet, den weiten Schelf vor dem Filchner-Ronne Schelfeis begeben, um die bereits in den Jahren 2013-2014 (FOS, Filchner Outflow System, PS82) und 2015-2015 (FROST, Filchner Outflow System Now, PS96) begonnenen ozeanographischen, biologischen und geologischen Untersuchungen fortzuführen und zu ergänzen (Abb. 1 u. 2).

Dieses Meeresgebiet ist besonders im Nordteil des Filchner Troges geprägt durch die Interaktion von sehr kaltem Eisschelfwasser (ISW, Ice Shelf Water) aus dem Süden mit dem warmen Tiefenwasser (WDW, Warm Deep Water) des Weddellmeeres. Durch diese Vermischung werden sowohl die Tiefen- (WSDW, Weddell Sea Deep Water) als auch Bodenwassertypen (WSBW, Weddell Sea Bottom Water) des Weddellmeeres gebildet, die für die globale Ozeanzirkulation und die Belüftung der tieferen Schichten der Weltmeere von großer Bedeutung sind.

Diese hydrographischen Besonderheiten am Kontinentalabhang des Weddellmeeres sind sehr wahrscheinlich auch die primäre Ursache für die erhöhten biologischen Aktivitäten in diesem Gebiet.

In Ergänzung zu den vorhergehenden Expeditionen soll auch der westliche Schelf bis in den Ronne Trog beprobt werden, um die Bildungsgebiete des hoch salinen Schelfwassers HSSW (High Salinity Shelf Water) genauer zu untersuchen. Diese dichte Wassermasse ist besonders als Antrieb für die Unter-Schelfeiszirkulation des Filchner-Ronne Schelfeises von großer Bedeutung.

Die Bildung von Tiefen- und Bodenwasser (WSDW/WSBW) im südlichen Weddellmeer ist sowohl qualitativ als auch quantitativ stark durch die Produktionsvorgänge von Schelfeis-wasser (ISW) unter dem Filchner-Ronne Schelfeis beeinflusst. Eigene hydrographische Messungen mit *Polarstern* im Jahr 1995 entlang der Filchner-Schelfeisfront zeigen, dass der Abbruch von drei sehr großen Eisbergen im Jahr 1986 und deren Gründung auf der flachen Berkner Bank, die Zirkulation und die Wassermassenbildung im Filchner-Trog signifikant modifiziert haben. Von diesem großen Abbruch ist immer noch der Eisberg A23A als Rest vorhanden und beeinflusst insbesondere die Meereissituation östlich und südlich seiner Position. Auch die angrenzenden Seegebiete zeigen deutliche Veränderungen in den Wassermassencharakteristika und Strömungsmustern im Vergleich zu Messungen aus den frühen 1980er Jahren. Neuere Messungen aus der Sommersaison 2013-2014 (PS82) und 2015-2016 (PS96) ergeben ein neues Bild, das den Ausstrom von ISW am Osthang des

Filchner-Troges zeigt. Modellszenarien mit dem finiten Elemente Modell FESOM ergeben klimabedingte Veränderungen des Küstenstroms, die zu einem erhöhten Zufluss von warmem Wasser (Modified Warm Deep Water - MWDW) ab Mitte des einundzwanzigsten Jahrhunderts in dieses Gebiet führen könnten. Diese Veränderungen betreffen zunächst den Filchner-Trog und beeinflussen dann die Zirkulation unter dem Filchner-Ronne Schelfeis. Sollten sich Veränderungen im HSSW im Bereich des Ronne Troges verglichen mit den letzten Messungen aus den Jahren 1995 und 1998 zeigen, so lassen sich die aus den Modellen errechneten Ergebnisse besser in die Klimavorhersage einordnen und die zukünftig höhere Abschmelzraten des Schelfeises erklären. Eine höhere Schelfeisdynamik mit häufigeren Eisbergstrandungen und eine Erhöhung der Wassertemperatur werden erheblichen Einfluss auf die Artenvielfalt des südlichen Weddellmeeres haben. Deshalb ist die Messung der Ist-Situation in diesem Gebiet so wichtig, auch um eventuell zukünftige Veränderungen der Wassermassen einordnen zu können.

Zusammen mit den Schelfeis Verankerungen, die seit dem Jahr 2015 kontinuierlich an 4 Lokationen Daten aus der Schelfeis Kaverne des Filchner-Eisstroms übermitteln, können die von *Polarstern* gemessenen Stationen direkt vor der Schelfeiskante wichtige Erkenntnisse über die Physik und Biologie des Gesamtsystems geben.

Die wichtigsten Forschungsziele der Expedition PS111 FROST sind:

- Charakterisierung der hydrodynamischen Prozesse und Wassermassen im Ronne Einstrom- und Filchner Ausstrom-System. Dabei soll die Rolle der Meeresboden -topographie für die Wassermassenzirkulation ebenso erfasst werden, wie die Raten von Tiefen- und Bodenwasserbildung unter Einbeziehung der Schmelzraten des Schelfeises. Es sind hier weitere Stationen im Ronne Trog sowie im West- und Südteil des Filchner-Troges geplant, die die Messungen von PS82 und PS96 ergänzen.
- Eine Abschätzung von möglichen zeitlichen Veränderungen dieser hydrographischen Prozesse mit Hilfe der 3 Verankerungen am Ostrand des Filchner-Troges bei 76°.
- 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 Filchnergebiet.
- Ergänzende Untersuchungen mit dem britischen AUV und dem ROV des AWI im Bereich der Schelfeiskanten.
- Erstellung eines Verbreitungsmusters von Rossrobben im südlichsten Bereich des Weddellmeeres.
- Beschreibung des Meereises vor dem FRIS (Filchner-Ronne Schelfeis) durch Beschreibung der Salzgehaltsstruktur, Messung der Driftparameter und der physikalischen Eigenschaften mit Hilfe direkter Messungen und durch ein Meereis-Bojen Programm.
- Messung der Turbulenzstruktur der unteren Atmosphäre mit Hilfe von LIDAR Messungen
- Untersuchungen zur Geochemie der Sedimente
- Erstmalige Messungen zur Verunreinigung des Meerwassers mit Mikroplastik aus dem südlichsten Teil des Weddellmeeres.

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

SUMMARY AND ITINERARY

The cruise leg PS111 FROST, Filchner Ronne Outflow System Tomorrow, will start on 19 January 2018 in Cape Town (South Africa) and will end on 14 March 2018 in Punta Arenas (Chile). *Polarstern* will sail directly to the ice-covered Atka Bay to supply the German station *Neumayer III*. Due to a variety of field campaigns in the back-country of the station, the logistic requirements are at the limits for the ship so that the length of stay near *Neumayer* will take this in to account. At *Neumayer* one berth will have to be exchanged so that during the whole cruise the ship will be used to its maximum capacity. If the ice situation allows, we will have a short scientific programme within the coastal current to test the equipment of all working groups. Then *Polarstern* will adjourn to its main scientific region, the vast shelf areas in front of the Filchner-Ronne ice shelf. Here an extensive oceanographic and biological programme will proceed and complete the station grid, which had already been started during the PS82 FOS campaign (Filchner Outflow System) in 2013/2014 and the PS96 FROSN expedition (Filchner Outflow System Now) in 2015/2016 (Figs. 1 and 2).

The wide southern shelf in front of the FRIS (Filchner Ronne Ice shelf) is characterized by the interaction of very cold ice shelf water (ISW) with the warm deep water (WDW) of the Weddell Sea. The mixture of both is able to build the Weddell Sea Deep Water (WSDW) as well as the Weddell Sea Bottom Water (WSBW) which act as the precursor of the deep waters of the global oceans and which are very important for their ventilation.

These hydrographical features mainly acting at the continental slope are supposed to be the primary cause converting this region into a biological "hotspot" as indicated by recent investigations.

As a supplement to the preceding expeditions the Ronne Trough is scheduled to measure the source area of the densest water mass, the High Salinity Shelf Water (HSSW). This water mass acts as the driver of the circulation in the ice shelf cavity and is therefore of great importance.

The formation of deep and bottom water (WSDW/WSBW) in the southern Weddell Sea is strongly influenced by flow of Ice Shelf Water (ISW) out of the Filchner-Ronne Ice cavity. Own hydrographic measurements along the Filchner Ice Front carried out with *Polarstern* in 1995, show that the breakout of three giant icebergs in 1986 and their grounding on the shallow Berkner Bank still modified the circulation and water mass formation in the Filchner Trough. Since then the iceberg A23A still exists and is responsible for the increased sea ice concentrations east and south of the iceberg's position.

Even the adjacent sea areas further east show significant changes in the water mass characteristics and flow patterns compared to measurements from the early 1980s. New measurements from the summer seasons 2013-2014 (PS82) and 2015-2016 (PS96) provide a new picture showing the outflow of ISW on the eastern flank of the Filchner Trough. Recent model scenarios with the finite element model FESOM indicate that a redirection of the coastal current into the Filchner Trough and underneath the Filchner-Ronne Ice Shelf during the twenty-first century would lead to increased inflow of warm MWDW waters (Modified Warm Deep Water) into the deep southern ice-shelf cavity. These changes will first effect the Filchner Trough and then the total circulation underneath the FRIS. If it is possible to detect also changes in the characteristics of the HSSW in the area of the Ronne trough compared to the last measurements in 1995 and 1998, the model predictions for the increased melting rates could be validated more precisely.

A higher shelf ice dynamic with higher numbers of iceberg scouring events and an increase in water temperature will significantly influence the biodiversity of the southern Weddell Sea.

In addition to the 4 ice shelf moorings, which continuously report the data since the FIS drilling programme in 2015 direct out of the Filcher ice stream cavity, the stations serviced by

Polarstern in front of the ice shelf edge are necessary to interpret the changes of water masses even for the future.

The main objectives of the PS111 (FROST) expedition are:

- to characterize the hydrographical features and water masses of the Filchner Ronne Outflow System, the role of bathymetry for current patterns, and the deep and bottom water formation rates with the related basal melting rates. More stations in the Ronne Trough as well as the western and southern part of the Filchner Trough are planned to supplement the measurements of PS82 and PS96;
- to calculate time variations of hydrographical processes by means of 3 long term moorings on the eastern flank of the Filchner Trough around 76° S;
- to investigate the biological production of the Filchner Outflow System and the high-energy turnover to subsequent trophic levels;
- to estimate the impact of possible changes in the hydrography and increasing shelf and sea ice dynamics on the biodiversity and ecosystem functioning of the southern Weddell Sea;
- to establish supplementary measurements by a British AUV and an AWI ROV near the ice shelf edge;
- to compile data on distribution patterns of Ross seals in the southernmost area of the Weddell Sea;
- to describe the sea ice in front of the FRIS (Filchner Ronne Ice Shelf) by measuring salinity, drift velocity and other physical parameter together with a sea ice buoy programme;
- to measure the turbulence structure of the lower atmosphere by a shipborne LIDAR;
- to investigate the geochemical content of the sediments; and
- to carry out first measurements on the microplastic content of sea water in the southernmost area of the Weddell Sea.

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

References

Schröder M (2016) The Expedition PS96 of the Research Vessel POLARSTERN to the southern Weddell Sea in 2015/2016. Reports on Polar and Marine Research, 700, 148 pp, http://doi.pangaea.de/10013/epic.48157.d001.

Knust R, Schröder M (2014) The Expedition PS82 of the Research Vessel POLARSTERN to the southern Weddell Sea in 2013/2014. Reports on Polar and Marine Research, 680, 155 pp, 10.2312/BzPM_0680_2014.

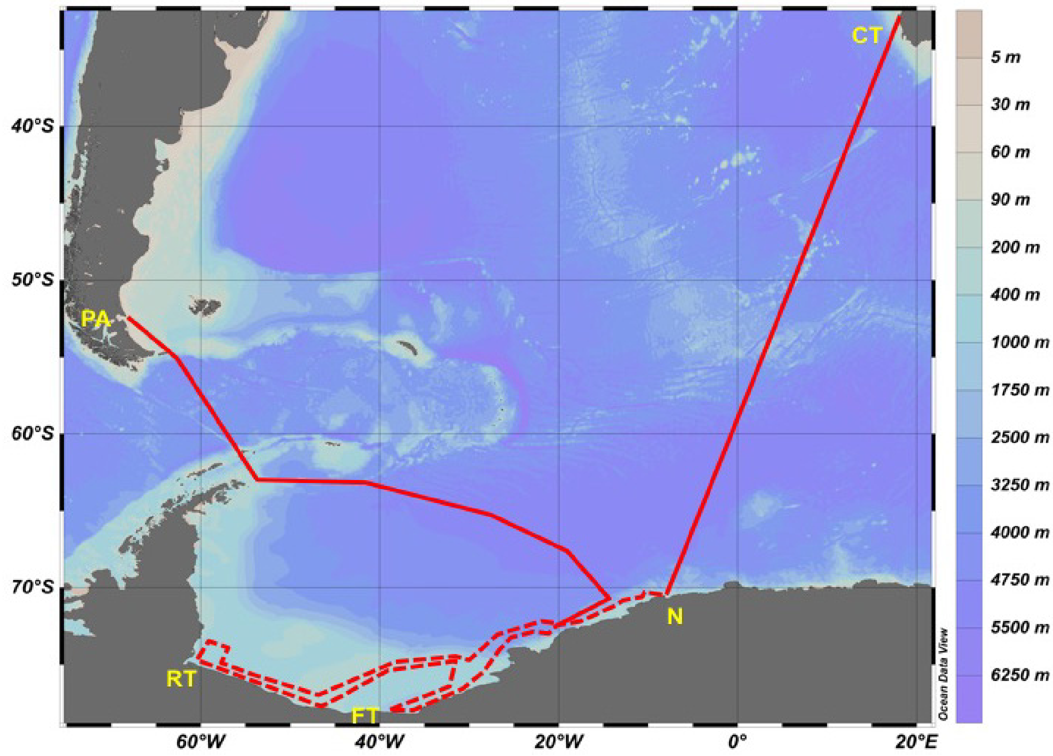


Abb. 1: Geplanter Fahrtverlauf PS111 mit den Abkürzungen CT= Cape Town, N= Neumayer, FT= Filchner Trough, RT = Ronne Trough und PA= Punta Arenas

Fig. 1: Planned route PS111 with the abbreviations CT= Cape Town, N= Neumayer, FT=Filchner Trough, RT= Ronne Trough and PA= Punta Arenas

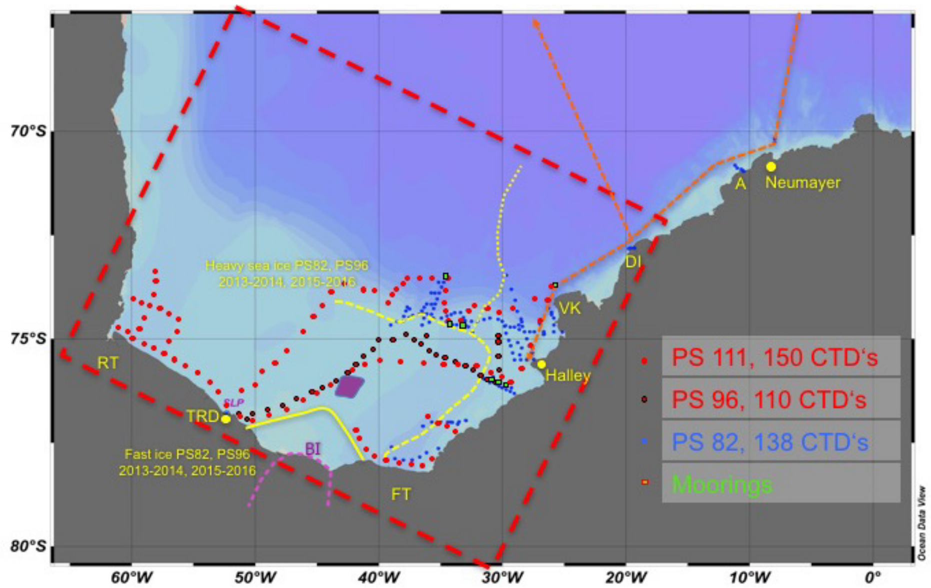


Abb. 2: Haupt-Untersuchungsgebiet mit geplantem Fahrtverlauf PS111. Es sind außerdem die Stationen der Fahrten PS96 (schwarz-rote Punkte) und PS82 (blaue Punkte) angegeben sowie die Verankerungspositionen (grüne und gelbe Quadrate). Zusätzlich ist der Festeisbereich der Saison 2013/2014 (gelbe Linie) und die Position des Eisbergs A23a (pink) angegeben.

Fig. 2: Main research area of the planned route PS111. The stations of the voyages PS96 (black-red dots) and PS82 (blue dots) are also indicated as well as the mooring positions (green and yellow squares). In addition, the landfast ice of the season 2013/2014 (yellow line) and the position of the iceberg A23a (pink) are shown.

2. OCEANOGRAPHIC CONDITIONS AND DISTRIBUTION OF OCEANIC TRACE GASES OFF FILCHNER-RONNE ICE SHELF, SOUTHERN WEDDELL SEA

Michael Schröder[1], Hartmut Hellmer[1], Markus Janout[1], Andreas Wisotzki[1], Jürgen Sültenfuß[2], Johanna Geilen[1], Yannick Kern[3,4], Svein Østerhus[3], Clara Stolle[4],[1]

[1]AWI
[2]Uni Bremen
[3]Uni Bergen
[4]Uni Kiel

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. 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 scales with flow out of the Filchner Ice Shelf cavity occurring on the western slope only during late summer/early fall. 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). 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 Filchner-Ronne Ice Shelf (FRIS) cavity (Hellmer et al., 2012). 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 freshwater 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 the melting at the base of ice shelves located downstream.

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

General objectives:

- Specify the physical properties controlling the flow across the Filchner Trough sill.
- Determine the temporal variability of the hydrography and tracer distribution in the Filchner Trough with regard to Ice Shelf Water outflow, Antarctic Bottom Water formation, Modified Warm Deep Water inflow, and High Salinity Shelf Water spreading.
- Identify temporal trends.
- Provide a comprehensive dataset for numerical model validation and initialisation of coupled ocean-ice shelf - ice sheet models.

Specific objectives:

- Determine the course of the coastal current in the south-eastern Weddell Sea and MWDW flowing towards the Filchner Ice Shelf front.
- Re-visit the Ronne Ice Shelf front for a new snapshot of the characteristics of HSSW, its spatial distribution, and spreading paths on the southern continental shelf.
- Provide an improved estimate of glacial melt water inventories and basal melt rates for the southern Weddell Sea (Filchner Ice Shelf) to deduce temporal trends in the future.

The combination of CTD casts from aboard *Polarstern* and its helicopters together with long-term moorings in the Filchner Trough and underneath the Filchner Ice Shelf aims to describe the present physical environment in the southern Weddell Sea, and to monitor its variability and the changes which might occur. Tracer observations will help to quantify:

- subglacial meltwater drainage and ice shelf basal melting (stable noble gas isotopes [^{3}He, ^{4}He, Ne] are used to determine basal glacial melt water inventories),
- Antarctic Bottom Water formation (transient trace gases [CFCs] to identify transit time scales and formation rates), and
- the variability of both compared to observations from previous expeditions, e.g., PS96 2015-2016.

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. A minimum of 150 ship-based CTD-casts, and another 30 helicopter-based CTD casts are planned to survey the area. From the full-depth profiling casts we intend to obtain about 600 water samples for noble gas isotopes and about 1,200 water samples for CFCs analyses. Since the water sample capability of the helicopter-deployed CTD system is limited, we will only take 2-3 samples from near the bottom and the surface at these sites. For the purpose of our objectives it is necessary to have stations/transects (1) close to the ice shelf front, (2) parallel and normal to the Filchner Trough axis, and (3) along the down-slope path of outflowing ISW/WSBW. The total station time of this proposal amounts to ca. 14 days (Fig. 2; helicopter operations are not assumed to consume relevant ship time). In cooperation with the Bjerknes Centre in Bergen, Norway, we plan to re-deploy three moorings at 76° S on the eastern flank of the Filchner Trough (yellow squares in Fig. 2), aimed to monitor the interplay between the southward flowing MWDW and the northward flowing ISW. These moorings will provide the seasonal variation of both water masses over a time span of 2 to 4 years.

Water samples for helium isotopes and neon will be stored in 50 ml gas tight copper tubes, which will be clamped of at both sides. The noble gas samples are to be analyzed at the IUP Bremen noble gas mass spectrometry lab. 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 again at the IUP Bremen (also see next chapter).

Three moorings along 76° S on the eastern flank of the Filchner Trough will have to be replaced again, which first had been launched in 2013 (PS82) and replaced during PS96 in 2015. The data of these moorings during the two years of operation (2013 to 2015) show a strong seasonality of modified warm water intrusions flowing south and cold ice shelf water flowing north. With a longer time-series these interpretations will have to be confirmed.

Expected results

- Extension (by two years) of the time series on the eastern slope of the Filchner Trough based on mooring data at 76°S.
- Filling the (hydrographic) gap between mooring site at 76°S and the Filchner Ice Shelf front.
- Additional information about the temporal variability of the spreading of Ice Shelf Water in the Filchner Trough.
- New snapshot of hydrographic conditions on the continental shelf in front of the Ronne Ice Shelf.

Data policy and 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 helium/neon and 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 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.

References

Foldvik A, Gammelsrod T, Osterhus S, Fahrbach E, Rohardt G, Schröder M, Nicholls KW, Padman L,

Woodgate RA (2004). Ice shelf water overflow and bottom water formation in the southern Weddell Sea. J. Geophys. Res. 109(C02015), doi:10.1029/2003JC002008.

Hellmer HH, Kauker F, Timmermann R, Determann J, Rae J (2012) Twenty-first-century warming of a large Antarctic ice-shelf cavity by a redirected coastal current, Nature, 485, 225-228.

Ryan S, Hattermann T, Darelius E, Schröder M (2017) Seasonal cycle of hydrography on the eastern shelf of the Filchner Trough, Weddell Sea, Antarctica, J. Geophys. Res, 122, 6437-6453, doi:10.1002/2017JC012916.

Timmermann R, Goeller S (2017) Response to Filchner-Ronne Ice Shelf cavity warming in a coupled ocean-ice sheet model – Part 1: The ocean perspective, Ocean Science, 13, 765-776, doi:10.5194/os-13-765-2017.

3. TRACE MEASUREMENTS (HE, NE; CFCS)

Jürgen Sültenfuß1, Pia Sültenfuß[1,2], Fanny Wischnewski[1], Oliver Huhn[1] (not on board)

[1]Uni Bremen
[2]Uni Oldenburg

Objectives

Our approach aims to quantify the basal ice shelf melting in the southern Weddell Sea and to investigate the related WSBW composition, its formation rate and export into the deeper Weddell Basin. It aims to enhance our understanding how basal shelf ice melting and WSBW formation evolve under changing climate conditions.

Investigating and quantifying basal glacial melting and the related WSBW formation as close as possible to its sources (Filchner Ice Shelf and Filchner Trench as its outflow area) will help to increase our understanding of the interaction of these unique Antarctic Ocean climate components under changing climate conditions. Tracer observations will help substantially to investigate and quantify basal glacial melting (stable noble gas isotopes [^{3}He, ^{4}He, Ne] to quantify basal glacial melt water inventories), basal melt rates and WSBW formation (transient trace gases [CFCs] to determine transit time scales and formation rates) and their variability (Fig. 3.1).

The aims of the proposed project are:

- To produce an improved actual estimate of basal glacial melt water inventories and basal melting rates for the ice shelves in the southern Weddell Sea (Filchner Ice Shelf) to be able to address temporal trends in the future
- To trace the pathways of the basal melt water, how it contributes to local Antarctic Bottom Water formation, and to quantify the related actual Antarctic Bottom Water formation rates
- To investigate the possible variability or to find evidence for temporal trends in glacial melting processes and related Antarctic Bottom Water formation. Possible variability could be detected by comparison with observations from previous expedition (i.e. PS96).

In the Weddell Sea, the actual state of basal ice shelf melting, its variability and possible future trends due to changing climate conditions are not yet fully understood. To assess basal glacial melt rates by observations and to understand its impact on the Weddell Sea Deep and Bottom Water composition and formation rate and related variability as well as the impact on the global ocean circulation more tracer observations are urgently needed.

A useful tool to identify and to quantify basal glacial melt water is the oceanic measurement of the low-solubility and stable noble gases helium (He) and neon (Ne) (Schlosser, 1986). Atmospheric air with a constant composition of these noble gases is trapped in the ice matrix during its formation. Due to the enhanced hydrostatic pressure at the base of the shelf ice, these gases are completely dissolved in the water, when the ice is melting from below. This leads to an excess of ^{4}He = 1060 %and Ne = 770 %in pure glacial melt water (Hohmann et al., 2002; excess means over the air-water solubility equilibrium). Frontal and surface glacial or sea ice melt water would equilibrate quickly and not lead to any noble gas excess. With an accuracy of 0.5 %for He measurements performed at the IUP Bremen, basal glacial melt water fractions of 0.05 %are detectable.

Anthropogenic transient trace gases (chlorofluorocarbons, CFCs) allow estimating the time scales of the renewal and ventilation of inner oceanic water masses and transport. They enter the ocean by gas exchange with the atmosphere. Since then the evolution of these tracers is determined on first order by their temporal increase in the atmosphere and subsequently by entrainment and advection in the ocean interior. Combining CFC based time scales with noble gas and multiparameter analysis allows to access basal glacial melting rates and the basal melt water induced water mass transformation rates (Huhn et al., 2008a).

Work at sea

On board we will take water samples for noble gases (^{3}He, ^{4}He and Ne) and CFCs. The sample acquisition does not demand additional ship time accept that for deployment and re-deployment of the CTD-water-sampler system on regular hydrographic stations.

We will take advantage of the existing CTD-water-sampler system. The water samplers (Niskin bottles) must be closed by stainless steel springs and not by rubber springs. Due to the high volatility and very low concentrations in the water we request to take our samples first (i.e., before oxygen, salinity, CO2, and others sampling) For one noble-gas sample we need 1,5 liter (incl. rinsing), for CFCs we need 0,5 liter (incl. rinsing). We need lab space for sample post processing and storage (e.g. one dry-lab on portside).

Expected results

Major goal of this project is to study the interaction of the Filchner-Ronne-Ice-Shelf (FRIS) and the ambient Filchner-Ronne-Outflow-System and water masses and subsequently the Weddell Sea and estimate the amount of basal melting and related Weddell Sea Deep and Bottom Water formation.

We will quantify state of the art basal melt water inventories and basal melt rates of the Filchner-Ronne-Ice-Shelf (FRIS). We will assess melt water path-ways, its entrainment into ambient water masses (Weddell Sea Deep and Bottom Water, Antarctic Bottom Water) and further circulation and export. This will provide a better understanding of the FRIS and Weddell Sea interaction based on observations. Furthermore, quantification of actual reference values for basal melt water inventories and basal melt rates will allow future investigation of variability or trends of its interaction with the (warming) ocean.

We expect to be able to separate gas contribution from melting of continental ice sliding on the bed rock by the combination of ^{3}He, ^{4}He and Ne.

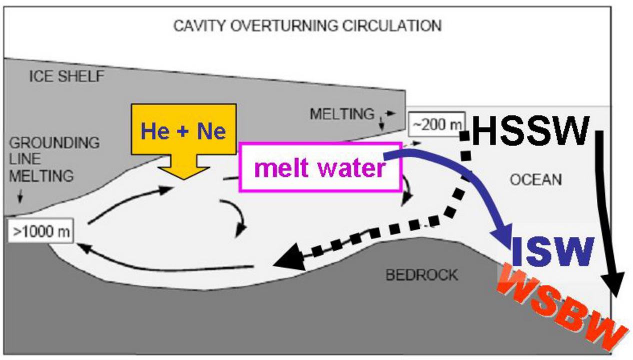


Fig. 3.1: Schematic of water mass transformation by interaction with the shelf ice. HSSW is flowing into the sub-glacial cavity, induces basal melting, and ISW is created. WSBW can be formed by HSSW ("Foster-Carmack process") or gmw/ISW ("Foldvik process"). Basal melting of the ice shelf can be traced by noble gases like He and Ne, released from air bubbles in the ice matrix.

Data management

After return of water samples for gas analysis to the IUP lab in Bremen GC technique for CFC analysis and mass spectrometer technique He isotope and Ne analysis is apply to the samples. An extended quality control will be performed by the operators and PI at the Bremen IUP Bremen.

Once published, all data sets will be transferred to data bases such as PANGAEA or sent to the German Oceanographic Data Center (DOD), where they will be available for the international scientific community. PANGAEA guaranties long-term storage of the data in consistent formats and provides open access to data after publication.

References

Hohmann, R., P. Schlosser, S. Jacobs, A. Ludin, R. Weppernig, 2002. Excess helium and neon in the southeast Pacific. Tracers for glacial meltwater. Journal of Geophysical Research, 107 (C11), doi. 10.1029/2000JC000378.

Huhn, O., H. H. Hellmer, M. Rhein, W. Roether, C. Rodehacke, M. Schodlok, and M. Schröder, 2008a. Evidence of deep and bottom water formation in the western Weddell Sea. Deep-Sea Research II, 55/8-9, pp. 1098-1116, doi:10.1016/j.dsr2.2007.12.015.

Huhn, O., M. Rhein, M. Hoppema, S. van Heuven, 2013. Decline of deep and bottom water ventilation and slowing down of anthropogenic carbon storage in the Weddell Sea, 1984-2011. Deep-Sea Research I, 76, 66-84. DOI: 10.1016/j.dsr.2013.01.005.

Schlosser, P., 1986. Helium. A new tracer in Antarctic oceanography. Nature, 321, 233-235.

4. SHIP-BASED WIND LIDAR MEASUREMENTS OF THE ANTARCTIC BOUNDARY LAYER (SWIANT)

Fabian Reiser[1], Frank Schnaase[1,2], Günther Heinemann[1] (not on board)

[1]Uni Trier
[2]AWI

Objectives

The representation of the atmospheric boundary layer (ABL) in the Antarctic is a major challenge for numerical weather forecast models and regional climate models. Reference data sets are rare, particularly over the ocean areas. Standard measurements on research vessels yield near-surface observations and one or two radiosonde launches per day. The group of the University of Trier will perform measurements of vertical and horizontal profiles of wind, turbulence and aerosols. We will use a wind lidar, which is a programmable scanner and can operate with a maximum range of 10 km. Radiosondes launched from *Polarstern* will be used for comparisons of the wind profiles. The data will be used for the verification of simulations using a high-resolution regional climate model and for process studies. The project was endorsed by the Polar Prediction Project (PPP) as a valuable contribution to the Year of Polar Prediction (YOPP).

Work at sea

We use a scanning wind lidar, which measures wind profiles in the ABL with a high vertical resolution (5 m) and a high temporal resolution (15 min). The wind lidar can operate with a maximum range of 10km. The used lidar is a programmable scanner, which enables vertical scans in all directions. The main scan patterns are the vertical azimuth display (VAD), the range-height indicator (RHI) and horizontal scans with fixed azimuth (STARE). The VAD is used for the determination of wind profiles above the lidar. The STARE mode is used at two or three azimuth angles, which are adjusted to the heading of the ship and the wind direction. The RHI mode is generally applied together with the STARE mode and at the same azimuth angles to obtain cross-sections. This allows for measurements of e.g. the internal boundary layer at the sea ice edge or ice shelf front. Since the lidar is not mounted on a stabilized platform, the ship's heading, roll and pitch angles are recorded using an Attitude Heading Reference System (AHRS), an external GPS and data from the ship's navigation system.

Continuous sampling of vertical profiles will be performed during the cruise. For intensive observation periods during the cruise, RHI and horizontal scans will be performed additionally yielding cross-sections of the ABL. Of particular interest are katabatic winds at Coats Land, the flow in the area of iceberg A23A, the internal boundary layer over the Ronne polynya and over sea ice leads. Radiosondes launched from *Polarstern* will be used for comparisons of the wind profiles (Heinemann and Zentek 2016).

Expected results

The measurements during the *Polarstern* cruise shall yield a data set of continuous and high-resolution vertical profiles of wind and aerosol backscatter. The data will be used for the verification of simulations using a high-resolution regional climate model and for process studies.111

Data management

All lidar data obtained during the cruise will be stored on a laptop and USB disks of the participants. After the cruise all lidar data will be stored at data servers of the University of Trier. The processed data will be stored in the PANGAEA data base.

References

Heinemann G, Zentek R (2016) Measurements of the atmospheric boundary layer using a wind lidar. In: The Expedition PS96 of the Research Vessel POLARSTERN to the southern Weddell Sea in 2015/2016 (ed. M. Schröder). Reports on Polar and Marine Research 700, Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, Germany, 148pp http://doi.pangaea.de/10013/epic.48157.d001.

5. SEA ICE PHYSICS

Stefanie Arndt[1], Nicolas Angelo Stoll[1], Ricarda Winkelmann[2], Ronja Reese[2], Marcus Huntemann[3], Dirk Notz[4] (not on board)

[1]AWI
[2]PIK Potsdam
[3]Uni Bremen
[4]MPI Hamburg

Objectives

Sea ice and snow are key variables in the global climate system. Through their manifold interactions with the atmosphere (e.g. the ice-albedo feedback) and ocean (e.g. freshwater budgets during melt and formation), they have strong impacts on global circulation patterns extending far beyond the polar regions. The year-around snow-cover on the ice dramatically alters these exchange processes. Therefore, seasonal transition processes during the freezing and melting season strongly affect snow properties and its volume, such as surface flooding, superimposed ice formation, and extensive snow metamorphism (Arndt et al., 2016; Eicken et al., 1994; Haas et al., 2001; Nicolaus et al., 2009). Given the increasing role of remote sensing observations for sea-ice research, snow cover properties become even more important, since they dominate most retrieval algorithms and data interpretation (Cavalieri et al., 2012; Kern and Ozsoy-Çiçek, 2016; Kern et al., 2016; Ricker et al., 2014; Schwegmann et al., 2015).

Much of the direct impact of sea ice on the underlying ocean is related to the release and storage of salt during sea-ice growth and melt. The release of salt from sea ice occurs generally only through gravity drainage during winter and, if air temperatures rise sufficiently to allow for substantial surface melting, through flushing with fresh water during summer (Notz and Worster, 2009). Because of the low air temperatures, the latter process is all but absent in the Antarctic, and gravity drainage is by far the most dominant process for the release of salt from sea ice. In recent years, we have come a long way in understanding (Notz and Worster, 2009), measuring (Notz et al., 2005) and simulating (Griewank and Notz, 2013) gravity drainage. Particularly for the Weddell Sea, strong progress has been made in monitoring and comparing sea-ice data. However, in order to understand the interaction of the sea-ice with the upper ocean and its role for ocean dynamics in general, *in-situ* measurements of the distribution of salt in sea ice are necessary.

Moreover, the variability of Antarctic sea ice, regarding sea-ice extent, concentration, and season duration, is significantly spatially heterogeneous (Kwok et al., 2017; Lee et al., 2017; Parkinson and Cavalieri, 2012; Stammerjohn et al., 2012; Turner et al., 2014). It is therefore necessary to study not only the seasonal and inter-annual evolution of sea ice, but to describe in particular the regional variability of key variables, such as sea-ice thickness, snow depth, and sea-ice drift (ECVs).

To achieve this, the Seasonal Snow and sea-ice Studies (SeaSonS) porgramme will perform sea-ice thickness and snow depth surveys, deployments of autonomous stations (buoys), and along-track ice observations from the bridge during PS111 (FROST). In addition, we will obtain physical properties of the sea ice and its snow cover during all ice stations. Those measurements are supposed to cover different spatial and temporal scales to allow an advanced understanding of the status and importance of Antarctic sea ice, with respect to its interactions in the climate system.

The data gained from this study will help to investigate the seasonal and interannual variability of sea-ice thickness, snow depth, sea-ice drift and deformation in the Weddell Sea close and in the Filchner Outflow System complementary to those done during ANT-XXIX/9 during austral summer 2013/14, ANT-XXX/2 during austral summer 2014/15 and PS96 during austral summer 2015/16.

Work at sea

The SeaSonS project focuses on the measurements of sea-ice physical properties by deploying autonomous systems (buoys) on several short ice stations in the Weddell Sea. Those buoys will stay on the sea-ice floes and will measure the temporal and spatial evolution of the sea-ice conditions for several months up to years. In order to investigate sea-ice thickness and snow accumulation, it is planned to deploy several sets of Ice Mass-balance Buoys (IMB) and Snow Buoys. Those buoys will be partly surrounded by drift buoys (so-called Surface Velocity Profilers, SVPs), which aim to relate dynamical processes and the temporal evolution of sea-ice and snow thickness. In addition, autonomous systems measuring the vertical salinity distribution (salt harps) as well as light profiles in the sea ice and snow column (light harps) complete the comprehensive description of the sea-ice floes. Complementary, current sea-ice and snow conditions will be measured by various methods at each buoy deployment site and on selected floes in the vicinity.

Moreover, in the vicinity of the fast-ice area in the southern Weddell Sea (Ronne/Filchner Trough), sea-ice thickness measurement flights by helicopter will allow to describe sea-ice mass balance processes also on a bigger scale.

Complementary information on the physical state of sea ice, including its concentration, the three most dominant ice classes and their respective coverage, ice floe structure as well as snow depth will be visually observed hourly from the bridge of *Polarstern*. Data will be documented together with the meteorological state and the location within a standardized protocol for such observations. Those data will contribute to the database of the ASPeCt programme, which already compiled data for about three decades, and is used to create and update a sea-ice thickness climatology for the Antarctic sea-ice area.

Expected results

Over all the collected data shall lead to a better understanding of seasonal and interannual variations of Antarctic sea ice. The transect data of snow depth and sea-ice thickness will contribute to similar measurements during earlier campaigns in similar regions and/or times. This will allow comparisons of the sea-ice conditions since 2013. The snow stratigraphy data will contribute to an improved understanding on seasonal mass budget variations in the Southern Ocean.

The time series from the (mainly) autonomous instruments will help to describe and quantify the progress of sea ice and snow throughout the seasonal cycle. These data sets are most likely important background data sets for other studies and will help to close observational gaps during less studied times of the year, compared to austral summer.

Data management

Scientific data will be submitted to PANGAEA upon publication as soon as the data are available and quality-assessed. We expect all data from SeaSonS 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).

References

Arndt S, Willmes S, Dierking W, Nicolaus M (2016) Timing and regional patterns of snowmelt on Antarctic sea ice from passive microwave satellite observations. Journal of Geophysical Research - Oceans, 121(8), 5916-5930, doi:10.1002/2015JC011504.

Cavalieri DJ, et al. (2012) A Comparison of Snow Depth on Sea Ice Retrievals Using Airborne Altimeters and an AMSR-E Simulator. IEEE Transactions on Geoscience and Remote Sensing, 50(8), 3027-3040, doi:10.1109/tgrs.2011.2180535.

Eicken H, Lange MA, Hubberten HW, Wadhams P (1994) Characteristics and distribution patterns of snow and meteoric ice in the Weddell Sea and their contribution to the mass balance of sea ice. Annales Geophysicae-Atmospheres Hydrospheres and Space Sciences, 12(1), 80-93, doi:10.1007/s00585-994-0080-x.

Griewank PJ, Notz D (2013) Insights into brine dynamics and sea ice desalination from a 1-d model study of gravity drainage. J. Geophys. Res., 118(7), 3370–3386, 10.1002/jgrc.20247.

Haas C, Thomas DN, Bareiss J (2001) Surface properties and processes of perennial Antarctic sea ice in summer. Journal of Glaciology, 47(159), 613-625, doi:10.3189/172756501781831864.

Kern S, Ozsoy-Çiçek B (2016) Satellite Remote Sensing of Snow Depth on Antarctic Sea Ice: An Inter-Comparison of Two Empirical Approaches. Remote Sensing, 8(6), 450, doi:10.3390/rs8060450.

Kern S, Ozsoy-Çiçek B, Worby AP (2016) Antarctic Sea-Ice Thickness Retrieval from ICESat: Inter-Comparison of Different Approaches. Remote Sensing, 8(7), 538, doi:10.3390/rs8070538.

Kwok R, Pang SS, Kacimi S (2017) Sea ice drift in the Southern Ocean: Regional patterns, variability, and trends. Elem Sci Anth, 5.

Lee SK, Volkov DL, Lopez H, Cheon WG, Gordon AL, Liu YY, Wanninkhof R (2017) Wind-driven ocean dynamics impact on the contrasting sea-ice trends around West Antarctica. Journal of Geophysical Research-Oceans, 122(5), 4413-4430, doi:10.1002/2016jc012416.

Nicolaus M, Haas C, Willmes S (2009) Evolution of first-year and second-year snow properties on sea ice in the Weddell Sea during spring-summer transition. Journal of Geophysical Research, 114(D17109), doi:10.1029/2008JD011227.

Notz D, Worster MG (2009) Desalination processes of sea ice revisited. J. Geophys. Res., 114, C05,006, doi: 10.1029/2008JC004885.

Notz D, Wettlaufer JS, Worster MG (2005) A non-destructive method for measuring the salinity and solid fraction of growing sea ice in situ. J. Glaciol., 51(172).

Parkinson, CL Cavalieri DJ (2012) Antarctic sea ice variability and trends, 1979-2010. Cryosphere, 6(4), 871-880, doi:10.5194/tc-6-871-2012.

Ricker R, Hendricks S, Helm V, Skourup V, Davidson M (2014) Sensitivity of CryoSat-2 Arctic sea-ice freeboard and thickness on radar-waveform interpretation. The Cryosphere, 8(4), 1607-1622.

Schwegmann S, Rinne E, Ricker R, Hendricks S, Helm V (2015) About the consistency between Envisat and CryoSat-2 radar freeboard retrieval over Antarctic sea ice. The Cryosphere Discuss., 9(5), 4893-4923, doi:10.5194/tcd-9-4893-2015.

Stammerjohn S, Massom R, Rind D, Martinson D (2012) Regions of rapid sea ice change: An inter-hemispheric seasonal comparison. Geophysical Research Letters, 39, doi:10.1029/2012gl050874.

Turner J, et al. (2014) Antarctic climate change and the environment: an update. Polar Rec, 50(3), 237-259, doi:10.1017/S0032247413000296.

6. ICE SHELVES IN A WARMING WORLD: FILCHNER ICE SHELF SYSTEM, ANTARCTICA

Adrian Jenkins[1], Stephen McPhail[2], Robert Templeton[2]

[1]BAS
[2]NOCS

Objectives

Ice shelves are the floating extensions of the Antarctic Ice Sheet that form where the ice is not thick enough to maintain contact with the seabed. They are sensitive to change both in the atmosphere above them and the ocean below. Any change can have far-reaching consequences because they regulate the flow of ice from the interior of the ice sheet (Alley et al. 2005), while their interaction with the ocean determines the fate of half the freshwater coming from the continent (Rignot et al. 2013). Temperatures that remain above freezing year-round and the enormous specific heat capacity of water make the ocean, through its role in melting ice from the underside of the ice shelves, the most significant agent of change. Understanding the processes that can deliver warmer ocean waters to the sub-ice-shelf environment is thus critical for projections of future ice loss from Antarctica and the resulting impacts on sea level and ocean circulation.

The Filchner Ice Shelf (FIS), in the southern Weddell Sea, is fed by five ice streams that together drain 19 % of the Antarctic continent. Although FIS currently appears to be stable, there are two principal but opposing hypotheses for how a warming climate might affect melt rates at its base. The first is that a reduction in sea-ice formation and the associated brine rejection to the north of the ice front leads to a lowering of the density of the cold continental shelf waters and a weaker circulation beneath the ice shelf, with reduced basal melting (Nicholls 1997). The second hypothesis, supported by a recent modelling study (Hellmer et al. 2012), is that a reduction in sea-ice thickness near the shelf break leads to stronger coupling between the wind and ocean, increasing the flux of warm water onto the continental shelf. The intrusion of warm water follows the Filchner Depression, from the shelf break to deep beneath FIS, resulting in dramatically higher ice shelf basal melt rates.

Critical to the transmission of an ocean warming signal beneath the ice are the currents that cross the ice front, a quasi-vertical wall of ice that extends ~500 m into the water. Since the currents experience planetary rotation and must conserve their angular momentum, they cannot readily cross such a step change in water column thickness. Thus the physical geometry puts a strong and as yet not fully understood constraint on the access of continental shelf waters to the sub-ice cavity. Early modelling studies suggested that complete isolation of the sub-ice cavity was possible (Determann & Gerdes 1993), although that was probably an artefact of the simple model geometry, with more realistic setups showing inflows and outflows that vary in time (Jenkins et al. 2004). Nevertheless, recent observation and high-resolution modelling (Darelius et al. 2014) suggest a complex circulation near the Filchner Ice Front in which waters flowing north along the western coast of the sub-ice cavity turn along the ice front to exit the cavity at the eastern coast, while the currents immediately north of the ice front flow in the opposite sense, from east to west.

This project aims to study that complex region near the ice front using an Autonomous Underwater Vehicle (AUV) to measure water properties and currents along a series of transects that cross the ice front, linking ship-based observations to the north with sub-ice observations in the south.

Work at sea

The AUV to be used for the study is AutosubLR (ALR), a long range (~1000 km) vehicle designed and built at the National Oceanography Centre Southampton. After deployment, a series of tests will be run in open water, during which ALR will be continuously monitored from *Polarstern*. Once the test runs have been successfully completed, ALR will be sent on four in/out transects extending ~35 km beneath the ice shelf, taking 20-24 hr each. While performing the transects ALR will operate entirely independently, and the ship will be free to undertake other work. Contact with the ship will be re-established following each transect to verify ALR's position and update its navigation data if necessary. It will then transit ~6 hr along the ice front to start the next in/out transect. Recovery on-board should not be necessary until completion of the final transect. Deployment and recovery require open water in the immediate vicinity (few km) of the ship. The work will take place at the Filchner Ice Front (76°S, 36-40°W), with the exact location to be determined when ice conditions are known. Although not critical, it would be scientifically beneficial and logistically convenient to deploy and recover ALR near CTD stations.

Expected Results

ALR will collect along-track measurements of temperature, salinity and microstructure data, as well as current profiles above and below its track. These data will enable us to reconstruct the horizontal circulation in the vicinity of Filchner Ice Front, from which we can determine the locations of inflow to, and outflow from, the sub-ice-shelf cavity, and the properties and mixing rates of the associated water masses.

Data management

We anticipate up to 30 GB of scientific and navigational data from the ALR deployment. Data will be downloaded as soon as a radio link is established with the vehicle and before recovery on board. Multiple copies will be made and shipped north via different routes. Data will be archived at the British Oceanographic Data Centre, with unrestricted access after two years

References

Alley RB, Clark PU, Huybrechts P, Joughin I (2005) Ice-sheet and sea-level changes. Science, 310, 456–460, doi: 10.1126/science.1114613.

Darelius E, Makinson K, Daae K, Fer I, Holland PR, Nicholls KW (2014) Hydrography and circulation in the Filchner Depression, Weddell Sea, Antarctica. Journal of Geophysical Research Oceans. 119, 5797–5814, doi: 10.1002/2014JC010225.

Determann J, Gerdes R (1993) Melting and freezing beneath ice shelves: implications from a three-dimensional ocean-circulation model. Annals of Glaciology, 20, 413–419.

Hellmer HH, Kauker F, Timmermann R, Determann J, Rae J (2012) Twenty-first-century warming of a large Antarctic ice-shelf cavity by a redirected coastal current. Nature, 485, 225–228, doi: 10.1038/nature11064.

Jenkins A, Holland DM, Nicholls KW, Schröder M, Østerhus S (2004) Seasonal ventilation of the cavity beneath Filchner-Ronne Ice Shelf simulated with an isopycnic coordinate ocean model. Journal of Geophysical Research Oceans 109, C01024, doi: 10.1029/2001JC001086.

Nicholls KW (1997) Predicted reduction in basal melt rates of an Antarctic ice shelf in a warmer climate. Nature, 388, 460–462.

Rignot E, Jacobs S, Mouginot J, Scheuchl B (2013) Ice-shelf melting around Antarctica. Science 341, 266–270, doi: 10.1126/science.1235798.

7. MORPHOLOGICAL INVESTIGATIONS ON THE CONTINENTAL SHELF IN FRONT OF THE FILCHNER-RONNE ICE SHELF

Jan Eric Arndt[1], Patricia Slabon[1], Anne Braakmann-Folgmann[1]
[1]AWI

Objectives

Knowledge of the seafloor morphology is essential basic information for various scientific disciplines of Antarctic research, i.e. marine geology, oceanography, biology and glaciology. Multibeam bathymetric surveys are the state-of-the-art technique to acquire high resolution seafloor data by insonifying a swath below a research vessel. In the southern Weddell Sea Embayment (WSE) multibeam acquisition has been carried out during several expeditions, predominantly as 'en route' measurements during transits but not as systematic surveys. Large data gaps still exist both in deep water and especially on the shallow continental shelf (Fig. 7.1). However, only detailed mapping of the seafloor morphology on the continental shelf can reveal glacial bedforms that can be used for reconstructing past grounded ice-sheet extent, flow pattern, bed conditions and style of retreat (e.g. Ó Cofaigh et al., 2008, Graham et al., 2009, Lavoie et al., 2015, Slabon et al. 2016, Arndt et al. 2017). Therefore, these morphological features provide information on past ice sheet dynamics which is crucial for improving ice-sheet models (e.g. DeConto and Pollard, 2016).

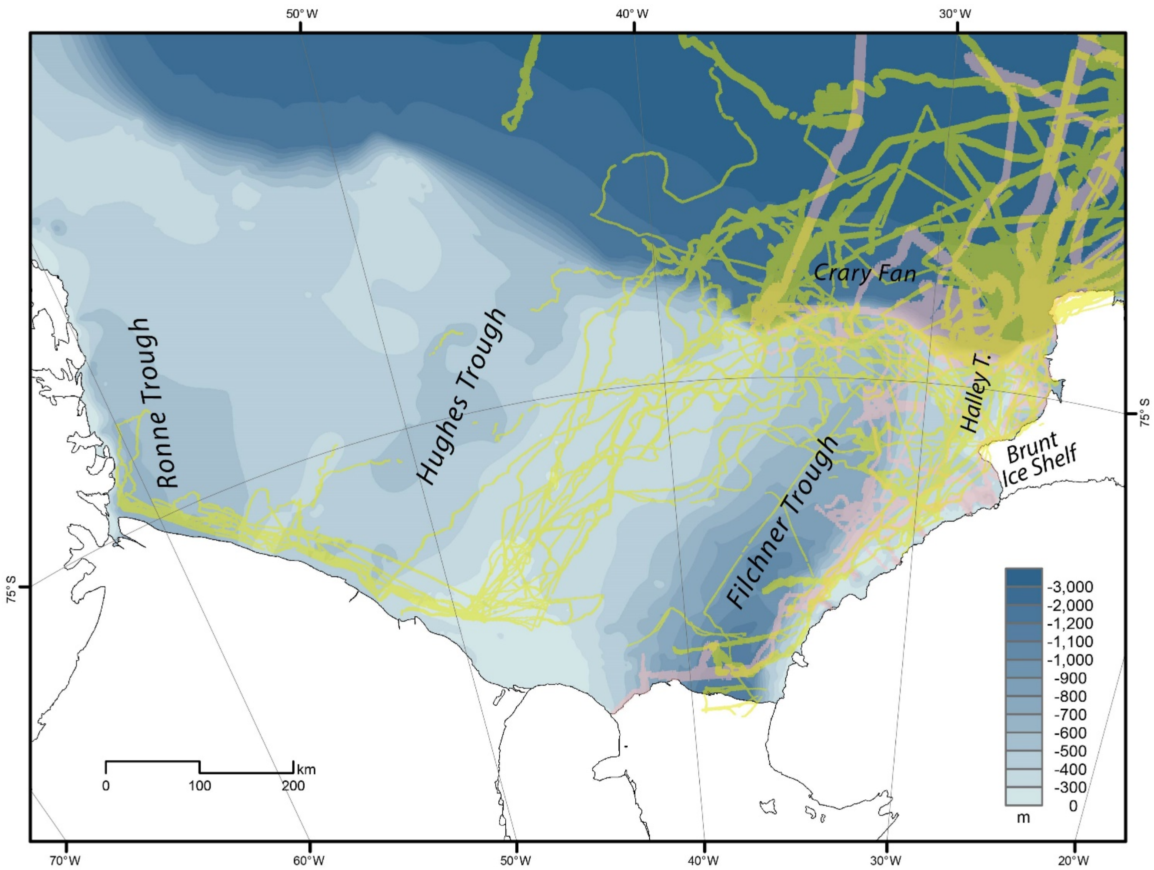


Fig. 7.1: Coverage of swath bathymetry acquired by the Alfred Wegener Institute (yellow) and the British Antarctic Survey (purple) in the southern Weddell Sea, background bathymetry from IBCSO V1.0 (Arndt et al. 2013)

Due to sparse data coverage in the remote southern WSE with its harsh ice conditions, its glacial history still remains poorly known. Hillenbrand et al. (2014) reviewed studies based on glacial-geological records in the study area and developed two alternative scenarios for the Last Glacial Maximum (LGM) ice sheet extent: 1) geomorphological and radiocarbon data suggest an ice sheet extension at least close to the shelf edge, 2) surface exposure age results from rock outcrops surrounding the Filchner-Ronne Ice Shelf show only minor thickening of ice and therefore suggest that ice did not ground in the deepest parts of the troughs. A recent investigation of new swath bathymetry, sub-bottom profiling data and sediment cores from the outer shelf part of Filchner Trough suggests that the trough was filled by an highly dynamic palaeo-ice stream that did not reach its maximum extent during the LGM but in the early Holocene (Arndt et al., accepted). A possible mechanism for this behavior is the interplay of the West Antarctic Ice Sheet with the East Antarctic Ice Sheet in the hinterland that possibly alternatingly drained ice trough Filchner Trough. Pre-dominantly single track lines of multibeam data directly in front of the ice shelf in Ronne Trough and Hughes Trough revealed the presence of glacial lineations on the seafloor and, hence, streaming ice at some time in the past (Stolldorf et al., 2012). A more comprehensive image of glacial landforms and, hence, the past extent and dynamics of the ice in these troughs remains unresolved until new data is acquired. These observations highlight, that the LGM to Holocene glacial history in the study area is complex and still poorly known. More data is needed to better understand the past ice sheet system and the processes involved.

In addition to an improved knowledge on glacial landform distribution and therefore the past ice sheet evolution, the acquired data will refine future regional bathymetric compilations as the International Bathymetric Chart of the Southern Ocean (IBCSO) (Arndt et al. 2013). These regional bathymetric models then will be used to update global bathymetric compilations like the General Bathymetric Chart of the Ocean (GEBCO) (Weatherall et al. 2015). Apart from these post-cruise products, the bathymetric data is also essential for other working groups on board to plan the deployment of gear and after sampling to set punctual information into relation to its surrounding environment.

Work at sea

The hull-mounted *Hydrosweep DS3* multibeam echosounding system will be used to collect swath bathymetric data during PS111. Data will be acquired during all times of transit. It is intended to process the acquired data and to perform a preliminary cleaning on board to directly be able to visualize the data for interpretation and possible site selection for other working groups. To complement the swath bathymetric data, sub-bottom profiler data will be acquired simultaneously with the hull-mounted *Parasound P70 system*. These data allow us to penetrate into the sub-seafloor and visualize its upper-most (depending on substrate up to 200 m) stratigraphy. The stratigraphy enables an improved interpretation of seafloor features and their formation processes. Furthermore, it is essential to identify locations for sediment sampling.

Expected results

Our work at sea will result in new high resolution maps of the seafloor and additional information on its sub-bottom stratigraphy. The new data in conjunction with previously acquired data will enable us to identify and map submarine landforms, i.e. of glacigenic origin. The improved knowledge on their distribution will allow us to improve our understanding of past ice sheet extent, dynamics and retreat in the studied area. This is crucial to improve our knowledge on glacial processes and, hence, current ice models that are used to predict the future development of the modern-day ice sheets. In addition, the new data will improve our knowledge on possible pathways for water masses on the continental shelf and will enable improved biological habitat studies.

Data management

All acquired bathymetric and sub-bottom profiler data will be stored in *PANGAEA*.

References

Arndt JE, Hillenbrand CD, Grobe H, Kuhn G, Wacker L (accepted) Evidence for a dynamic grounding line in outer Filchner Trough, Antarctica, until the early Holocene. Geology.

Arndt JE, Jokat W, Dorschel B (2017) The last glaciation and deglaciation of the Northeast Greenland continental shelf revealed by hydro-acoustic data. Quaternary Science Reviews, 160, 45-56, doi:10.1016/j.quascirev.2017.01.018.

Arndt JE, Schenke HW, Jakobsson M, Nitsche FO, Buys G, Goleby B, Rebesco M, Bohoyo F, Hong J-K, Black J, Greku R, Udintsev G, Barrios F, Reynoso-Peralta W, Taisei M, Wigley R (2013) The International Bathymetric Chart of the Southern Ocean (IBCSO) Version 1.0 - A new bathymetric compilation covering circum-Antarctic waters. Geophysical Research Letters, 40, 3111-3117, doi:10.1002/grl.50413.

DeConto RM, Pollard D (2016) Contribution of Antarctica to past and future sea-level rise. Nature, 531, 591-597, doi:10.1038/nature17145.

Graham AGC, Larter R.D, Gohl K, Hillenbrand C-D, Smith JA, Kuhn G (2009) Bedform signature of a West Antarctic palaeo-ice stream reveals a multi-temporal record of flow and substrate control. Quaternary Science Reviews, 28, 2774-2793, doi:10.1016/j.quascirev.2009.07.003.

Hillenbrand C-D, Bentley MJ, Stolldorf TD, Hein AS, Kuhn G, Graham AGC, Fogwill CJ, Kristoffersen Y, Smith JA, Anderson JB, Larter RD, Melles M, Hodgson DA, Mulvaney R, Sugden DE (2014) Reconstruction of changes in the Weddell Sea sector of the Antarctic Ice Sheet since the Last Glacial Maximum. Quaternary Science Reviews, 100, 111-136, doi:10.1016/j.quascirev.2013.07.020.

Lavoie C, Domack EW, Pettit EC, Scambos TA, Larter RD, Schenke HW, Yoo KC, Gutt J, Wellner J, Canals M, Anderson JB, Amblas D (2015) Configuration of the Northern Antarctic Peninsula Ice Sheet at LGM based on a new synthesis of seabed imagery. The Cryosphere, 9, 613-629, doi:10.5194/tc-9-613-2015.

Ó Cofaigh C, Dowdeswell JA, Evans J, Larter RD (2008) Geological constraints on Antarctic palaeo-ice-stream retreat. Earth Surface Processes and Landforms, 33, 513-525, doi:10.1002/esp.1669.

Slabon P, Dorschel B, Jokat W, Myklebust R, Hebbeln D, Gebhardt C (2016) Greenland ice sheet retreat history in the northeast Baffin Bay based on high-resolution bathymetry. Quaternary Science Reviews, 154, 182-198, doi:10.1016/j.quascirev.2016.10.022.

Stolldorf T, Schenke H-W, Anderson JB (2012) LGM ice sheet extent in the Weddell Sea: evidence for diachronous behavior of Antarctic Ice Sheets. Quaternary Science Reviews, 48, 20-31, doi:10.1016/j.quascirev.2012.05.017.

Weatherall P, Marks KM, Jakobsson M, Schmitt T, Tani S, Arndt JE, Rovere M, Chayes D, Ferrini V, Wigley R, (2015) A new digital bathymetric model of the world's oceans. Earth and Space Science, 2, doi:10.1002/2015ea000107.

8. FORAGING ECOLOGY OF ROSS SEALS IN THE SOUTH-WESTERN WEDDELL SEA

Marthán N. Bester[1], Mia Wege[1], Horst Bornemann[1]

[1]MRI
[2]AWI

Objectives

The Ross seal (*Ommatophoca rossii*) is the least studied of Antarctic phocids (Bester & Hofmeyr 2007; Southwell et al. 2008). In particular, estimating the circumpolar population status of the Ross seal has proved nigh impossible (Southwell et al. 2008; Bengtson et al. 2011). Their ranging behaviour is poorly known (Southwell et al. 2012) but they appear to forage beyond the pack-ice region outside of the breeding and moulting seasons (Blix & Nordøy 1998, 2007; Arcalís-Planas et al. 2015), suggesting that they may be more pelagic rather than ice-loving (Nordøy & Blix 2001; Arcalís-Planas et al. 2015). In this context, they are also being described as "commuters" (Kooyman & Kooyman 2009). Apart from the description of a few stomach contents and scats (Øritsland 1977; Skinner & Klages 1994), inferences from diving patterns (Bengtson & Stewart 1997; Blix & Nordøy 2007) and haulout data (Southwell et al. 2005) from only a few individuals, the diet and foraging behaviour of the Ross seal are largely unknown. As climate change is now known to be affecting the oceans (Levitus et al. 2000; Lyman et al. 2010, United Nations 2017), it is widely anticipated that impacts on marine mammals will be mediated primarily via changes in prey distribution and abundance (Simmonds & Isaac 2007; Siniff et al. 2008; Kovacs et al. 2012), which has management implications (Trathan & Agnew 2010). Additionally, the physical environmental changes, including thinner and less extensive seasonal ice formation linked to increased water (and air) temperatures and ocean acidification will result in alterations to the forage base of marine mammals (Siniff et al. 2008). This presumably includes density and distributional shifts in their prey, as well as potential losses of some of their favoured prey species (Kovacs & Lydersen 2008). This study therefore aims to obtain a comprehensive picture of the Ross seal's foraging activity in a three-dimensional environment and gain an understanding of seal behaviour in the context of both biological and physical parameters of the marine ecosystem (*cf*. Bowen 1997) in the eastern and southwestern Weddell Sea, and in view of a proposed development of a CCAMLR Marine Protected Area (MPA) in the Weddell Sea (Teschke et al. 2013, 2016). To this end, work carried out successfully from aboard SA *Agulhas II* along the east coast of the Weddell Sea in 2016 (Figure 8.1) shall be continued towards the area around the Filchner Trough and the Filchner-Ronne Ice Shelves with *Polarstern* in 2018.

The project builds on earlier seal research initiatives of the South African National Antarctic Programme (SANAP) in the pack-ice off Dronning Maud Land (e.g. Condy 1976; Skinner & Westlin-van Aarde 1989; Bester & Skinner 1991; Skinner & Klages 1994; Bester & Odendaal 2000; Bester et al. 2002), extend the pioneering work of Bengtson & Stewart (1997), Nordøy & Blix (2001, 2002) and Blix & Nordøy (2007), using technology such as Temperature and Depth Satellite Relay Data Loggers (SRDLs) (Boehme et al. 2009), stable-isotope analyses (Rau et al. 1992; Aubail et al. 2011), and ship-board strip (Condy 1977; Bester et al. 1995), and line-transect census studies (Bester & Odendaal 2000; Bester et al. 2014) to characterise Ross seal distribution, diet and physical characteristics of the water column where they forage as a contribution to detailing the structure and function of the pack-ice ecosystem (Ackley et al. 2003) and beyond. Although inferring diet from diving behaviour, habitat use and stable isotope analyses from samples is indirect and circumstantial (Southwell et al. 2012), it will be enhanced by data from vomitus and opportunistic scat collections. Such a mix and match of various techniques is likely to improve our insight on ecosystem trophic dynamics in a spatial and temporal context.

Work at sea

Ross seals will be investigated through deploying satellite-linked temperature-time-depth data loggers on them to measure diving and ranging behaviour of individuals and, through the use of stable isotope analyses on sampled blood, fur and whiskers and opportunistic scat and vomitus samples, their diet.

During PS111 we aim to:

- deploy SPLASH10-309A satellite linked position, temperature time-depth recorders (Wildlife Computers, Redmond, USA) to determine horizontal movement, haul-out, diving behaviour and frequented water temperatures (n = 3),
- deploy SPOT-300s satellite position and temperature tags (Wildlife Computers, Redmond, USA) to determine horizontal movement, haul-out, and water temperatures (n = 10) to enlarge the satellite data pool for Ross seal migration and diving behaviour,
- approach Ross seals that are encountered on ice floes to record size/mass, collect scats and vomitus (if available), blood, fur and whisker samples (n < 30), and
- collect associated oceanographic and meteorological data using the *Polarstern* on-board automated recording systems,
- conduct 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 & Odendaal 2000; Southwell et al. 2012), this will, however, provide opportunities to locate Ross seals, and to broadly compare with results from similar ship-board surveys during earlier expeditions (e.g. Condy 1976, 1977; Bester et al. 1995; Bester & Odendaal 2000; Bester et al. 2017),
- using helicopter flights ahead of the *Polarstern* within the pack-ice areas, in the time slot 10:00 – 16:00 LAT, the most likely period during which the Ross seals are hauled out on the ice floes, to locate Ross seals for temporary capture and instrumentation, and
- when the ship is expected to remain stationary for an extended period, a vigil during daylight hours will be kept on an observer rotational basis, to locate and access Ross seals for instrument deployment in the immediate vicinity of the ship.

Expected results

To obtain a comprehensive picture of the Ross seals' foraging activity in a three-dimensional environment it is necessary to understand seal behaviour in the context of both biological and physical parameters of the seals' marine environment in the Southern Ocean. The reconciliation of the obtained seal data with oceanographic data and the seasonal, inter-annual, and long-term changes in the marine habitat of seals will improve our understanding of the structure and dynamics of the Antarctic (and sub-Antarctic) marine ecosystem, contribute to the understanding of the status of Ross seal populations, and individual movements of Ross seals on a regional level. The comprehensive analysis and synthesis of biological and physical data perceivably could make an important contribution to determining relationships between hydrographic features, ocean currents, sea floor characteristics, prey dynamics, and the distribution and abundance of marine top predators. To this end we shall:

- investigate the ranging and diving behaviour of Ross seals in an area of high relative abundance off *Neumayer Station III*, and along the Ice Shelves of Dronning Maud Land and within the Filchner Trough region,
- research their diet through direct (vomitus and scat collecting) and indirect (dive behaviour and stable isotope analyses) means,

- compare their (and the other ice-breeding seal species') distribution and abundance on the cruise track of *Polarstern* with earlier ship-board surveys, to the end of improving our knowledge of the way oceanographic conditions affect the rarest of the four true Antarctic species of seal breeding off the Princess Martha Coast, Dronning Maud Land (SA *Agulhas II* SANAE 55 expedition 2016), and in the Filchner Trough area (*Polarstern* PS111 expedition 2018), Antarctica, with a view to using them as bioindicators of apparent environmental change (van Franeker 1992; Reid & Croxall 2001; Weimerskirch et al. 2003), perhaps due to global climate change, and
- extend the research previously done during PS82 of the *Polarstern* to the southern Weddell Sea in 2013/2014 (Bester et al. 2014).

Data management

Satellite linked SPLASH and SPOT tags (Wildlife Computers, Redmond, USA) transmit signals to the polar orbiting ARGOS satellites which relay received signals via the Centre de Localisations Satellites (CLS) in Toulouse, France, where the location data undergo a certain precision filtering algorithm before they are being harvested for further manufacturer-specific processing and cloud-based downloads. The latter will be ensured weekly by FIELAX, Bremerhaven, Germany, for further post-processing and aggregation of data. The resulting primary data will be uploaded in PANGAEA following an established work-flow. The PANGAEA database contains a large set of circum-Antarctic oceanographic data relevant to the proposed project, and has already been extensively used for seal tracking data. 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).

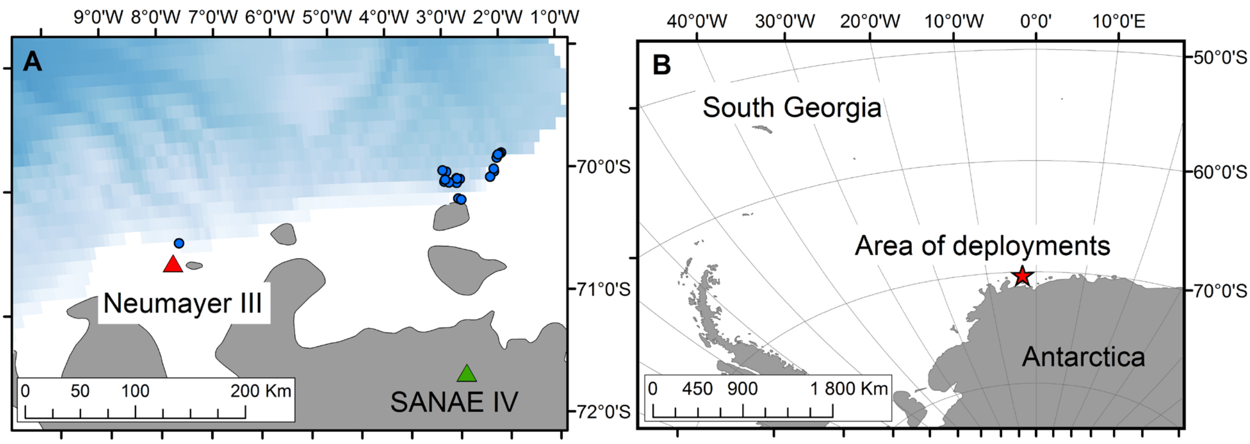


Fig. 8.1: (A) Deployment locations (blue dots) of Ross seals (Ommatophoca rossii) during the SANAE 55 expedition with SA Agulhas II in January 2016. The German base, Neumayer III, and the South African base, SANAE IV, are also indicated in the map. (B) The area where deployments were made in 2016 (star) in relation to the Weddell Sea and South Georgia.

References

Ackley SF, Bengtson JL, Boveng P, Castellini M, Daly KL, Jacobs S, Kooyman GL, Laake J, Quetin L, Ross R, Siniff DB, Stewart BS, Stirling I, Torres JJ, Yochem PK (2003) A top-down, multidisciplinary study of the structure and function of the pack-ice ecosystem in the eastern Ross Sea, Antarctica. Polar Record, 39, 219-230.

Arcalís-Planas A, Sveegaard S, Karlsson O, Harding KC, Wahlin A, Harkonen T, Teilmann J (2015) Limited use of sea ice by the Ross seal (*Ommatophoca rossii*), in Amundsen Sea, Antarctica, using telemetry and remote sensing data. Polar Biology, 38, 445–461.

Aubail A, Teilmann J, Dietz R, Riget F, Harkonen T, Karlsson O, Rosing-Asvid A, Caurant F (2011) Investigation of mercury concentrations in fur of phocid seals using stable isotopes as tracers of trophic levels and geographical regions. Polar Biology, 34, 1411–1420.

Bengtson JL, Stewart BS (1997) Diving patterns of a Ross seal (*Ommatophoca rossii*) near the eastern coast of the Antarctic peninsula. Polar Biology, 18, 214-218.

Bengtson, JL, Laake JL, Boveng P, Cameron MF, Stewart BS (2011) Distribution, density, and abundance of pack-ice seals in the Amundsen and Ross Seas, Antarctica. Deep-Sea Research Part II, 58, 1261-1276.

Bester MN, Ferguson JWH, Jonker FC (2002) Population densities of pack ice seals in the Lasarev Sea, Antarctica. Antarctic Science, 14, 123-127.

Bester MN, Hofmeyr GJG (2007) Ross Seal. In: Encyclopedia of the Antarctic, (Ed) B. Riffenburgh, Taylor & Francis Books Inc., New York, pp 815-816.

Bester MN, Odendaal PN (2000) Abundance and distribution of Antarctic pack ice seals in the Weddell Sea. In: Davison W, Howard-Williams C, Broady P (Eds). Antarctic Ecosystems: Models for Wider Ecological Understanding. Caxton Press, Christchurch, pp51-55.

Bester MN, Oosthuizen WC, Steinhage D, Bornemann H (2014) Abundance and distribution of seals, pp 116-125 in Knust R, Schröder M (eds) The Expedition PS82 of the Research Vessel POLARSTERN to the southern Weddell Sea in 2013/2014, Berichte zur Polar- und Meeresforschung = Reports on polar and marine research, Bremerhaven, Alfred Wegener Institute for Polar and Marine Research, 680, 155 p.Bester MN, Skinner JD (1991) South African research on Antarctic seals. South African Journal of Antarctic Research, 21, 165 – 166.

Bester MN, Wege M, Lübcker N, Postma M, Syndercombe G (2017) The Ross seal in eastern Weddell Sea, Antarctica. Polar Biology (submitted).

Blix AS, Nordøy ES (1998) Ross seal diving behaviour and distribution: A reassessment? New Zealand Natural Scientist, 23(Suppl), 14.

Blix AS, Nordøy ES (2007) Ross seal (*Ommatophoca rossii*) annual distribution, diving behaviour, breeding and moulting, off Queen Maud Land, Antarctica. Polar Biology, 30, 1449-1458.

Boehme L, Lovell P, Biuw M, Roquet F, Nicholson J, Thorpe SE, Meredith MP, Fedak M (2009) Technical note: Animal-borne CTD-Satellite Relay Data Loggers for real-time oceanographic data collection. Ocean Science, 5, 685-695.

Condy PR (1976) Results of the third seal survey in the King Haakon VII Sea, Antarctica. South African Journal of Antarctic Research, 6, 2-8.

Condy PR (1977) Results of the fourth seal survey in the King Haakon VII Sea, Antarctica. South African Journal of Antarctic Research, 7, 10-13.

Kooyman MM, Kooyman GL (2009) History of pinniped studies in Antarctica. Aquatic Mammals, 35(4): 523–556.

Kovacs KM, Lydersen C (2008) Climate change impacts on seals and whales in the North Atlantic Arctic and adjacent shelf seas. Science Progress, 91(2), 117–150.

Kovacs KM, Aquilar A, Aurioles D, Burkanov V, Campagna C, Gales, N (2012) Global threats to pinnipeds. Marine Mammal Science, 28(2), 414-436.

Levitus S, Antonov JI, Boyer TP, Stephens C (2000) Warming of the world ocean. Science, 287, 2225-2229.

Lyman JM, Good SA, Gouretski W, Ishii M, Johnson GC, Palmer MD, Smith DM, Willis JK (2010) Robust warming of the global upper ocean. Nature, 465, 334-337.

Nordøy ES, Blix AS (2001) The previously pagophilic Ross seal in now rather pelagic. Proceedings of the VIII SCAR International Biology Symposium, Amsterdam, The Netherlands, August 27-September 1, 2001, S5O14.

Nordøy ES, Blix AS (2002) Distribution and food consumption of Ross seals (*Ommatophoca rossii*) and leopard seals (*Hydrurga leptonyx*). In: Report of the Norwegian Antarctic Research Expedition 2000/01, J.G. Winther (ed.). Norsk Polarinstitutt Rapportserie, 120, 55-57.

Øritsland T (1977) Food consumption of seals in the Antarctic pack ice. In: Llano, G.A. (Ed.). Adaptations Within Antarctic Ecosystems. Smithsonian Institute, Washington DC, 749-768.

Rau GH, Ainley DG, Bengtson JL, Torres JJ, Hopkins TL (1992) $^{15}N/^{14}N$ and $^{13}C/^{12}C$ in Weddell Sea birds, seals, and fish: implications for diet and trophic structure. Marine Ecology Progress Series, 84, 1-8.

Reid K, Croxall JP (2001) Environmental response of upper trophic-level predators reveals a system change in Antarctic marine ecosystem. Proceedings of the Royal Society of London B. 268, 366-384.

Simmonds MP, Isaac SJ (2007) The impacts of climate change on marine mammals: early signs of significant problems. Oryx, 41(1), 19-26.

Siniff DB, Garrott RA, Rotella YJ, Fraser WR, Ainley DG (2008) Projecting the effects of environmental change on Antarctic seals. Antarctic Science, 20(5), 425–435.

Skinner JD, Westlin-van Aarde LM (1989) Aspects of reproduction in female Ross seals (*Ommatophoca rossii*). Journal of Reproduction and Fertility, 87, 67-72.

Skinner, JD, Klages NTW (1994) On some aspects of the biology of the Ross seal *Ommatophoca rossii* from King Haakon VII Sea, Antarctica. Polar Biology 14: 467-472. Southwell C, Paxton CGM, Borchers D, Boveng P, Nordøy ES, Blix AS (2008) Estimating population status under conditions of uncertainty: the Ross seal in east Antarctica. Antarctic Science, 20, 123-133.

Southwell C (2005) Optimising the timing of visual surveys of crabeater seal abundance: haulout behaviour as a consideration. Wildlife Research, 32, 333-338.

Southwell C, Bengtson J, Bester MN, Blix AS, Bornemann H, Boveng P, Cameron M, Forcada J, Laake J, Nordøy E, Plötz J, Rogers T, Southwell D, Steinhage D, Stewart BS, Trathan P (2012) A review of data on abundance, trends in abundance, habitat use and diet of ice-breeding seals in the Southern Ocean. CCAMLR Science, 19, 49-74.

Teschke K, Bornemann H, Bombosch A, Brey T, Brtnik P, Burkhardt E, Dorschel B, Feindt-Herr H, Gerdes D, Gutt J, Hain S, Herata H, Jerosch K, Knust R, Kock KH, Pehlke H, Schluter M, Schwarzbach W, Siegel V, Strass V, van Opzeeland I, von Nordheim H. 2013. Progress report on the scientific data compilation and analyses in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica), SC-CAMLR-XXXII, (BG/07), pp 1-29.

Teschke K, Beaver D, Bester M, Bombosch A, Bornemann H, Brandt A, Brtnik P, De Broyer C, Burkhardt E, Dieckmann G, Douglass L, Flores H, Gerdes D, Griffiths H, Gutt J, Hain S, Hauck J, Hellmer H, Herata H, Hoppema M, Isla E, Jerosch K, Kock KH, Krause R, Kuhn G, Lemke P, Liebschner A, Linse K, Miller H, Mintenbeck K, Nixdorf U, Pehlke H, Petrov A, Schröder M, Shust K, Schwegmann S, Siegel V, Thomisch K, Timmermann R, Trathan P, van de Putte A, van Franeker JA, van Opzeeland I, von Nordheim H & Brey T. 2016. Scientific background document in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica), Part A: General context of the establishment of MPAs and background information on the Weddell Sea MPA planning area. CCAMLR WG-EMM-15/38, 89 pp.

Trathan PN, Agnew D (2010) Climate change and the Antarctic marine ecosystem: an essay on management implications. Antarctic Science, 22, 387-398.

United Nations (2017) The First Global Integrated Marine Assessment, World Ocean Assessment I. Cambridge University Press, Cambridge, ISBN 9781316510018, 976 pp.

Van Franeker JA (1992) Top predators as indicators for ecosystem events in the confluence zone and marginal ice zone of the Weddell and Scotia Seas, Antarctica, November 1988 to January 1989 (EPOS Leg 2). Polar Biology, 12, 93-102.

Weimerskirch H, Inchausti P, Guinet C, Barbraud C (2003) Trends in bird and seal populations as indicators of a system shift in the Southern Ocean. Antarctic Science, 15, 249-256.

9. COMBINED EFFECTS OF TEMPERATURE AND ORGANIC MATTER AVAILABILITY ON DEGRADATION ACTIVITY BY ANTARCTIC BACTERIOPLANKTON

Klaus Jürgens[1], Christian Meeske[1], Judith Piontek (not on board)[2]

[1]IOW
[2]GEOMAR

Objectives

Global warming poses new threats to marine ecosystems since rising seawater temperature potentially induces cascading effects in biogeochemical cycles and food webs. In Antarctic marine systems, low seawater temperature, and the low availability of labile organic matter are major environmental constraints on bacterial growth and degradation activity. However, temperature and the availability of resources for heterotrophic bacteria undergo considerable change induced by climate warming combined with subsequent ice melt and changes in primary productivity. The relevance for bacterial productivity and subsequent CO_2 release by natural communities of the polar oceans is still unclear. The overarching goal of this project is to explore the synergistic potential of temperature and the availability of labile organic matter to increase heterotrophic bacterial degradation activity in Antarctic marine systems. Field sampling combined with on-board experiments will investigate bacterial remineralization and its dependence on temperature and substrate concentration in the Weddell Sea. Previous microbiological studies revealed high shares of psychrotolerant bacterial isolates, suggesting a high responsiveness of bacterioplankton in the Weddell Sea to rising temperature (Delille, 1992; Helmke and Weyland, 1995). However, the temperature sensitivity of natural communities, its spatial variability and the potential of increasing temperature to alter organic matter degradation has not been investigated so far.

Work at sea

During PS111, transects from coastal areas to the open sea and from low to high ice coverage, provide natural gradients in organic matter concentration and bacterial composition, will be sampled. Bacterial biomass production at different incubation temperatures will be measured on board, and samples for bacterial cell numbers, analysis of bacterial community composition and the analysis of organic matter (dissolved organic carbon and nitrogen, dissolved carbohydrates, dissolved amino acids) will be collected for later analysis.

Furthermore, on-board experiments will investigate combined effects of warming and substrate addition on bacterial production, bacterial community composition, patterns in gene expression and organic matter turnover in order to link changes in community structure and functioning to warming and substrate supply. The impact of rising temperature will also be examined with regard to the role of small protists as bacterivorous grazers and the resulting changes in top-down control on planktonic bacteria.

Expected results

This project will elucidate the modulation of temperature effects on heterotrophic bacterial activity by the availability of reactive organic matter and investigate the synergistic potential of combined effects. It will also take into account the temperature impact on bacterial community composition and the trophic link to bacterivores. Expected results will provide estimates of temperature effects on Antarctic bacterioplankton and resulting feedback to the ocean-atmosphere CO_2 exchange in a warming Antarctic. A better determination of bacterial remineralization and its dependence on substrate concentration and temperature will help to parameterize global models that aim to project the marine carbon cycle under a changing climate.

Data management

All data collected and generated by this project will be submitted to the central Pangaea database of SPP 1158. DNA and RNA sequence data will be submitted to public databases (Genbank, NCBI).

References

Delille D (1992) Marine bacterioplankton at the Weddell Sea ice edge, distribution of psychrophilic and psychrotrophic populations. Polar Biology, 12, 205-210.

Helmke E, Weyland, H (1995) Bacteria in sea ice and underlying water of the eastern Weddell Sea in midwinter. Marine Ecology Progress Series, 117, 269-287.

10. PTEROPODS AS EARLY-WARNING SYSTEM OF OCEAN ACIDIFICATION IN THE WEDDELL SEA

Silke Lischka[1], Jan Michels[2], Stanislav N. Gorb[2]

[1]GEOMAR
[2]Uni Kiel

Objectives

At high latitudes, thecosome pteropods (marine pelagic mollusks) can dominate zooplankton communities and consequently are important food web components in the pelagial. Due to their calcium carbonate shell made of aragonite, they significantly contribute to ocean carbon flux and are particularly vulnerable to ocean acidification. Despite their prominent role in the pelagic ecosystem and biogeochemistry, knowledge of the importance of thecosome pteropods for the Weddell Sea zooplankton community is scarce. Recent studies provide evidence for a significant invasion of anthropogenic CO_2 into the Weddell Sea Gyre between 1973 and 2008 having led to a decrease in pH and the saturation state of aragonite. This potentially perils thecosomes by inducing shell dissolution. The present project aims at establishing thecosome pteropods as early-warning organisms of ocean acidification in the Weddell Sea. To this end, the current 'shell dissolution state' will be investigated in relation to the prevailing ocean carbonate chemistry conditions at the main depths of pteropod occurrence to enable the assessment of the present condition of pteropods and to serve as a benchmark for potential future monitoring of ongoing ocean change processes. Samples to be obtained during this cruise will furthermore serve to describe the ecological (abundance, biomass) and biogeochemical (organic and inorganic carbon contribution) role of thecosome pteropods in the Weddell Sea zooplankton ecosystem.

Specific objectives:

- characterising the current shell dissolution state of thecosome pteropods in detail in relation to prevailing physical and chemical water properties using different electron microscopy techniques and methods
- determining the spatial and vertical distribution patterns of thecosome pteropods in relation to prevailing physical and chemical water properties

- assessing the ecological and biogeochemical importance of thecosome pteropods within the mesozooplankton community of the southern Weddell Sea in terms of their organic and inorganic biomass contribution

Work at sea

This project will be based on sampling with a MultiNet (150 µm mesh size), a Bongo Net (300 µm mesh size) and a CTD rosette. At as many CTD stations as possible in ice-free waters on four potential transects in the Filchner Trough area, zooplankton will be collected from the upper surface layers down to depths of approximately 500 m. With the MultiNet, samples will be taken by means of vertically stratified hauls (possible depth strata: 0–50 m, 50–100 m, 100–200 m, 200–300 m, 300–500 m; the final decision will be made on board according to the oceanographic conditions) to resolve the depth distribution of pteropods and to allow the collection of early pteropod developmental stages with smaller sizes. The Bongo Net with the larger mesh size will be used to quantitatively collect (by means of vertically integrated hauls) late pteropod developmental stages that might escape from nets with smaller mesh sizes. In addition to the zooplankton samples, water samples will be taken at the same depth intervals as the zooplankton samples by means of the CTD rosette to analyse dissolved nutrients (phosphate, nitrate, nitrite, silicate) and carbonate chemistry parameters (total alkalinity, pH, DIC). These analyses are necessary to be able to describe the *in-situ* living conditions of the pteropods and to directly link the pteropod occurrence and distribution patterns to the prevailing oceanographic conditions. Onboard, individuals of different pteropod developmental stages will be sorted out from the zooplankton samples and frozen or chemically fixed for later microscopic analyses of their shells at Kiel University. The water samples and the remaining portions of the zooplankton samples will be preserved for later determinations of the carbonate chemistry and the zooplankton abundances and biomasses in the home laboratories at GEOMAR.

Expected results

This project will provide information about the current shell dissolution state of thecosome pteropods in the Weddell Sea and specify if and to what extent these organisms have already been affected by recent and ongoing anthropogenic CO_2 invasions in the Weddell Sea. Furthermore, the abundance of thecosome pteropods and their ecological and biogeochemical significance within the mesozooplankton community of the Weddell Sea will be described and assessed. These results will allow establishing pteropods as early-warning organisms for future evaluations of global change processes in the Weddell Sea.

Data management

All data collected and generated by this project will be made publicly available via the World Data Center PANGAEA. All parts of the zooplankton samples not used for analyses will be stored at GEOMAR and be available for potential future analyses.

11. QUANTIFYING ELEMENTAL FLUXES WITH RADIUM ISOTOPES ACROSS THE ACC, IN THE WEDDELL GYRE AND IN THE FILCHNER-RONNE REGION

Claudia Hanfland[1], Marc Diego Feliu[2], Walter Geibert[1] (not on board)

[1]AWI
[2]Uni Barcelona

Background and Objectives

Our proposal aims at a better understanding of the role of upwelling deep water and shelf sources in the process of iron enrichment in surface waters, sea ice and adjoining shelf ice. While iron concentrations are generally very low in Southern Ocean polar waters, they sustain large blooms of phytoplankton that can cover regions up to 600,000 km^2 (Geibert et al. 2010). The origin of the iron necessary for primary production is still not yet clear. One hypothesis is input of this trace metal through various input paths (upwelling, melting icebergs that carry terrestrial material, and dust deposition as a minor source) followed by concentration in sea ice. With the onset of the melting season, the iron will be released into surface waters and support plankton growth.

To investigate the origin of iron, radioactive tracers from the U-Th-decay chains provide suitable information on the movement of water masses. ^{226}Ra is a well-established tracer that is enriched in intermediate and deep waters. High-resolution sampling of this tracer will enable us to identify regions with enhanced upwelling (e.g. Maud Rise) in high resolution.

^{228}Ra is a suitable isotope to trace shelf waters off the coast and in the open ocean. It has been sampled before in some coastal regions of the Weddell Sea, but not in the Southeastern Weddell Sea, and not in combination with iron. Shiptime permitting, the aim is to get the first samples for both ^{228}Ra and iron, which has never been done before in the Atlantic Sector of the Southern Ocean. In detail, the suggested work will aim to:

- Determine the source strength of the Filchner region for ^{228}Ra and Fe in order to estimate the importance of this shelf for productivity in the Weddell Sea
- Use improved precision in ^{226}Ra measurements to trace the fate of deep upwelled water in the surface of the Weddell Gyre and its link to macronutrients
- Couple deep upwelling to basal melting (in combination with oceanography)
- Determine sedimentation rates of sediments on the Filchner shelf (in combination with geology)

Work at sea

Iron input paths

While the role of iron in limiting primary productivity has been extensively studied by biologists, possible input paths into the remote waters of the otherwise nutrient-rich Southern Ocean are far from being well understood. Reliable, measured iron concentrations are scarce. In fact, only two sections exist to-date for the Atlantic sector of the Southern Ocean. A section published by Klunder et al. (2011; Fig. 11.1) highlights the role of submarine volcanism (e.g. around Bouvet island) and gives a first hint for iron release on the Antarctic shelf. A second section across the Weddell Sea (Klunder et al. 2014; Fig. 11.2) confirms relatively low deep iron concentrations in most places, but it also shows a prominent source at the shelf and slope near the Antarctic Peninsula (Fig. 11.2). Release from sediments can also be detected by the shorter-lived tracer ^{228}Ra, which is a prominent tracer for shelf sources (Charette et al. 2016).

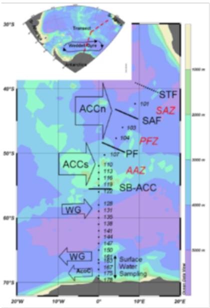
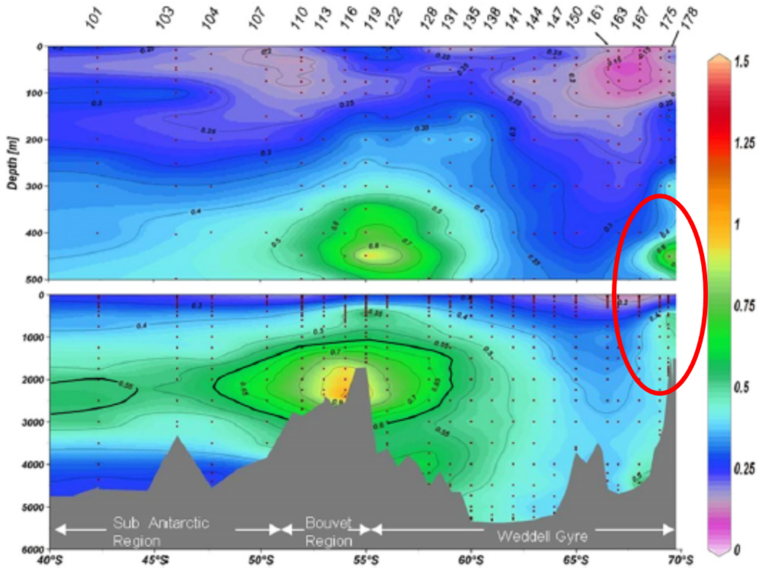



Fig. 11.1: Distribution of dissolved iron in the Eastern Weddell Gyre (Klunder et al. 2011)

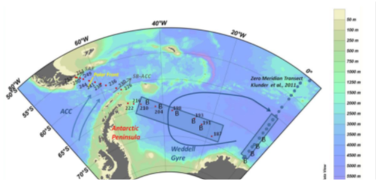
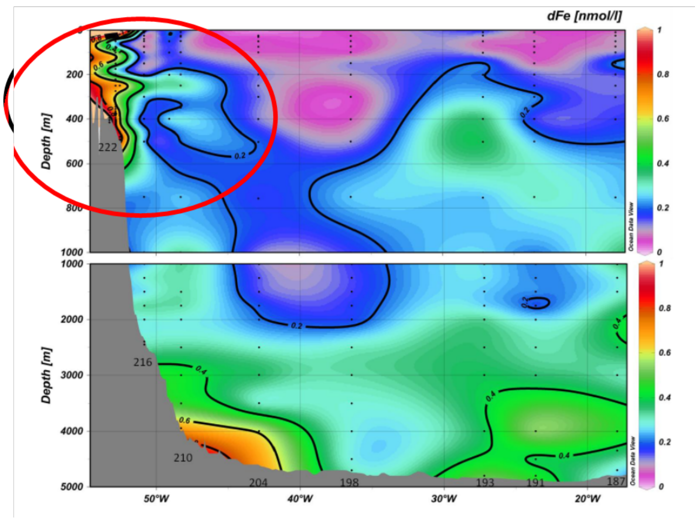



Fig. 11.2: Distribution of dissolved iron in the Weddell Sea (Klunder et al. 2011)

With the suggested proposal, aiming at sampling as far South as 78°S, we hope to bring proof about the strength of the shelf source in delivering iron to the Weddell Sea waters, closing a gap in an important potential source region for iron, and elucidate the role of sea and shelf ices in concentrating and releasing the trace metals.

^{226}Radium

Surface water activities of ^{226}Ra were investigated by Hanfland (2002). The most salient feature in the distribution of ^{226}Ra is a strong southward increase from approximately 8 dpm/100kg north of the Polar Front to about twice as much in the Weddell Gyre with a mean activity in the southern waters of the Antarctic Circumpolar Current (ACC) and within the Weddell Gyre of about 15.5 dpm/100kg (Fig. 11.3). This gradual increase of the ^{226}Ra activity is closely related to a drop-in temperature and displays the effect of upwelling of deeper waters.

It can be observed on all transects although the gradients differ in intensity. Highest values coincide with the location of Maud Rise, a topographic feature at 66°S, 3°E. Maud Rise is an oceanic plateau of volcanic origin that rises from to 1600 m below the sea surface. It is a region known for enhanced upwelling where large polynyas in the sea ice cover are a recurrent feature (Muench et al. 2001; Holland 2001). Dissolved silicate has been found to have a similar distribution to ^{226}Ra in this region, with a similar source in deep upwelling as a possible key mechanism. The preferred site for polynya formation is a warm water region southwest of Maud Rise which is consistent with high heat fluxes.

Upwelling is different between the Eastern and Western part of the Weddell Gyre and can be traced by ^{226}Ra. ^{227}Ac, another unstable isotope with a half-life of 22 years, had been investigated intensively by Geibert et al. (2002) and proved to be a suitable tracer to calculate upwelling rates in this area.

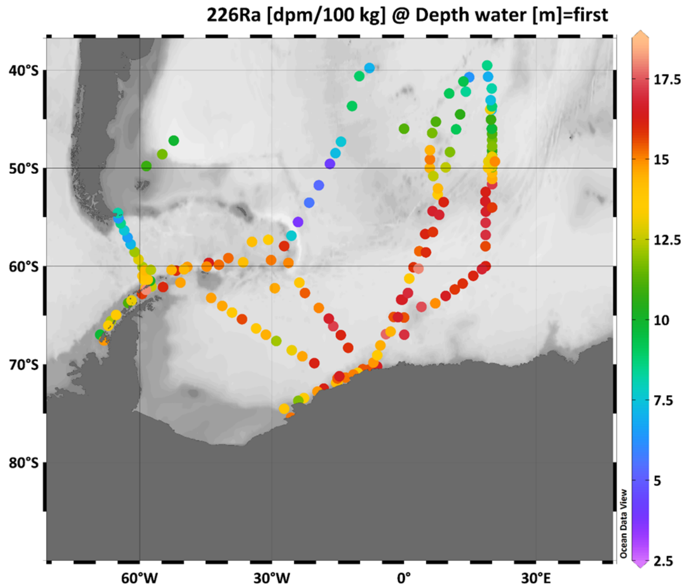


Fig. 11.3: Distribution of ^{226}Ra in the Atlantic sector of the Southern Ocean. Data: Hanfland (2002)

^{228}Radium

^{228}Ra originates from mostly from sediments. Due to this specific source and its shorter half-life of about 5.8 years, it is virtually absent in upwelling deep waters. Instead, it is found enriched near the ocean/continent boundary (Fig. 11.4), and it can be used to trace water masses that have chemically exchanged material with the sea-floor (Charette et al. 2016). This is illustrated by Fig. 11.4. Also highlighted by Fig. 11.4 is the fact that the Southwestern boundary of the Weddell Gyre, possibly a substantial source of continental material to the Weddell Gyre, is virtually unsampled for ^{228}Ra. Having similar sources, but a shorter half-life, ^{224}Ra has been used to study sedimentary sources near the Antarctic Peninsula (Annett et al. 2013).

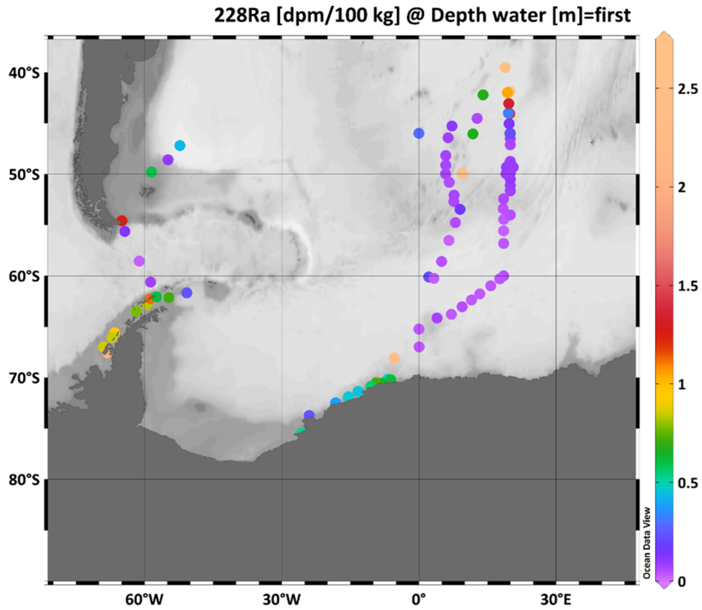


Fig. 11.4: Distribution of ^{228}Ra, a tracer for recent shelf contact, in the Atlantic sector of the Southern Ocean. No information from the Filchner region available. Data: Hanfland (2002)

Work at sea

Work at sea will focus on water samples and on porewater from sediment cores. In detail, we aim to sample:

- ^{226}Ra and ^{228}Ra from the ship's sea water supply. Analytical progress now allows to measure ^{226}Ra precisely on 1 Liter of sea water. ^{228}Ra, in contrast, needs to be pre-concentrated from larger volumes of sea water. Macronutrients will be sampled in parallel
- ^{226}Ra and ^{228}Ra from rosette casts.
- Subsamples of 50 ml each will be taken for nutrient analysis parallel to each Radium sample. Again, nutrient samples will be deep frozen for analysis back in the home lab.
- Clean surface water and/or ice samples away from the ship for trace metal (notably iron) analysis. Handheld devices only, as no clean CTD available on board
- Pore water sampling on multicorer (MUC) sediment cores for estimation of trace metal/radium ratios.

Expected results

We expect two main resulting datasets, allowing an improved understanding of biogeochemical fluxes in the region:

- A very precise ^{226}Ra/nutrient relationship, allowing a closer look at the interaction between upwelling and particle export across the frontal regions.
- The first determination of activities of ^{228}Ra from the Filchner region, possibly a very important source for shelf-derived inputs. Together with existing ^{228}Ra-analyses from other parts of the Weddell Gyre, this will allow to close the budget for ^{228}Ra in the region. If sampling allows, direct measurements of iron concentrations in possible sources (sediments, sea-ice) can be linked to ^{228}Ra to determine fluxes. Without direct iron analyses, interpretations are still possible using literature data from comparable regions.

In summary, we expect a step forward in understanding the supply of macro- and micronutrients to the Weddell Gyre.

Data management

All data collected during the expedition will be stored in the Open access library PANGAEA (Data Publisher for Earth & Environmental Science), hosted by AWI and MARUM. Radium data will be submitted to the Geotraces data base (GDAC).

References

Annett AL, Henley SF, van Beek P, Ganeshram R, Venables HJ, Meredith MP, Geibert W (2013) Use of radium isotopes to estimate mixing rates and trace sediment inputs to surface waters in northern Marguerite Bay (Antarctic Peninsula). Antarctic Science 25 (3), 445-456, doi:10.1017/S0954102012000892.

Charette MA, Lam PJ, Lohan MC, Kwon EY, Hatje V, Jeandel C, Shiller AM, Cutter GA, Thomas AL, Boyd PW, Homoky WB, Milne A, Thomas H, Andersson PS, Porcelli D, Tanaka T, Geibert W, Dehairs F, Garcia-Orellana J (2016) Coastal ocean and shelf-sea biogeochemical cycling of trace elements and isotopes: lessons learned from GEOTRACES. Philosophical Transactions A.

Geibert W, Assmy P, Bakker, DCE, Hanfland C, Hoppema M, Pichevin LE, Schröder M, Schwarz JN, Stimac I, Usbeck R, Webb A (2010) High primary productivity in an ice melting hot spot at the eastern boundary of the Weddell Gyre. Global Biogeochemical Cycles, 24, GB3007. doi:10.1029/2009GB003657.

Hanfland C (2002) ^{226}Radium and ^{228}Radium in the Atlantic sector of the Southern Ocean. Berichte zur Polarforschung, 431, 135 p., hdl:10013/epic.10436.

Holland DM (2001) Explaining the Weddell Polynya - a Large Ocean Eddy Shed at Maud Rise. Science, 292, 1697 – 1700.

Klunder MB, Laan P, DeBaar HJW, van Ooijen JC (2011) Dissolved iron in the Southern Ocean (Atlantic sector). DSR II, 58, 2678 – 2694. Doi: http://dx.doi.org/10.1016/j.dsr2.2010.10.042.

Klunder MB, Laan P, DeBaar HJW, Middag R, Neven I van Ooijen JC (2014) Dissolved Fe across the Weddell Sea and Drake Passage: impact of DFe on nutrient uptake. Biogeosciences, 11, 651-669.

Muench RD, Morison JH, Padman L, Martinson D, Schlosser P, Huber B, Hohmann R (2001) Maud Rise revisited. JGR, 106, C2, 2423 – 2440.

12. BENTHIC COMMUNITIES IN THE SOUTH-EASTERN WEDDELL SEA

Claudio Richter[1], Nils Owsianowski[1], Henning Schröder[1], Lena Heins[1], Sandra Maier[1,2]

[1]AWI
[2]NIOZ

Objectives

On Antarctic shelves, sponges and other filter-feeders often dominate the megabenthic epifauna (Arntz et al. 1994), but the factors governing their distribution and patchiness are only poorly understood. Food supply and ice-berg scour are believed to be play antagonistic roles in the build-up and removal of benthic biomass, explaining much of the observed patchiness (Clarke et al. 2004). A benthic disturbance experiment (BENDEX) was initiated in 2003/2004 (PS65) to mimic the effect of ice-berg scour on the rich benthic communities in Austasen area and assess the resilience of the benthic community to this physical disturbance (Gerdes et al.

2008). A 1000 x 100 m area was effectively stripped from its epibenthic cover by trawling and re-visited in later expeditions (PS77 in 2011, PS82 in 2013/14) showing only slow recovery compared to recently shelf-ice exposed areas in the Antarctic Peninsula/western Weddell Sea. Unfortunately, a subsequent attempt to access the BENDEX area during PS96 failed due to fast-ice, but the break-up of the fast-ice in the austral summer of 2017 offers an opportunity to revisit BENDEX in 2018 and assess the state of benthic recovery one and a half decades after initiation of the experiment.

Benthic oxygen uptake rate measurements are important to characterize the various habitats and estimate their demand for organic matter (Glud 2008). Considering the existing data on fauna abundance for the Weddell Sea shelf, it is timely and highly relevant to investigate the community respiration also as a function of biomass and diversity. The Weddell Sea shelf offers contrasting sites of benthic biomass with high values along its eastern margin and lower values in the western and southern areas (Voß 1988). It is crucial for our understanding of bentho-pelagic coupling to measure how much the patchy primary production is imprinted on the benthic carbon mineralization below and to supplant current P/B estimates with community respiration measurements.

An exploratory remotely operated vehicle (ROV) survey during the PS96 ice-camp in Drescher Inlet led to the discovery of a community of arcturid isopods living on the underside of the >80 m thick shelf-ice. It is not known so far, how these benthic filter-feeders have populated their peculiar habitat, what role they play in the Antarctic ecosystem and to what extent the measured densities are representative for other parts of the Weddell Sea ice shelf and beyond.

The objectives of this study are thus three-fold: (i) to repeat the surveys in the BENDEX and control areas to assess the dynamics of Antarctic benthic communities, (ii) to carry out benthic process studies relating benthic biomass to oxygen uptake and remineralization, and (iii) to explore the "hanging gardens" discovered in Drescher Inlet in other parts of the Weddell Sea in relation to potential factors governing the "seeding" of the shelf-ice with benthic organisms (e.g. rising platelet ice) and food supply (e.g. tidal currents).

Particularly, we aim

- to assess the status of the recovery of benthic communities in the area of the long-term benthic disturbance experiment (BENDEX) started in 2003, in comparison with the natural benthic community dynamics
- to assess the benthic oxygen fluxes and sediment oxygen profiles in relation to benthic biomass and the re-mineralisation of organic matter in sediments
- to identify the abundance and spatial distribution of *Antarcturus spinacoronatus* on the face and underside of the shelf-ice in relation to bottom-up (food concentration, currents) and top-down factors (supply by platelet ice, removal by predators) governing the occurrence of "hanging gardens" at local and regional scales
- to assess the diet and metabolism (respiration, egestion) of *Antarcturus spinacoronatus* on the shelf-ice to assess its ecological role in the Weddell Sea

Work at sea

Within the context of the benthic working programme of the PS111 cruise, seabed imaging will be carried out with a ROV in the BENDEX area and control sites visited on previous expeditions. The ROV is equipped with HD video, still camera, laser spacers, altimeter and CTD, and thus allows us to investigate the abundance, distribution, composition and diversity of the epimegafauna in its environmental context. Repeat transects of ROV tracks carried out on earlier cruises will allow to monitor changes in epibenthic groups over time and assess the communities dynamics over decadal time scales.

A Multigrab sampler (MG) will be deployed to collect benthic samples in BENDEX and control sites for abundance, biomass and biodiversity.

A Multicorer (MUC) will be deployed in cooperation with the geological team in BENDEX and control sites. Cores will be analyzed for sediment profiles and incubated for benthic oxygen uptake measurements as a function of macrobenthic biomass.

Within the context of the ice-shelf work, imaging of the ice-shelf from the surface to its underside will be carried out with the ROV. A brush-sampler, successfully deployed during PS96, will allow us to collect isopod samples for subsequent analyses of population genetics, diet and onboard incubations.

Expected results

Pending ice conditions, we expect to finalize a 14-yr benthic disturbance and recolonization experiment on the eastern Weddell Sea continental shelf. We expect to underpin our findings on temporal changes in benthic abundance and biomass with instantaneous rate measurements in benthic oxygen uptake in disturbed and control areas. Finally, we expect to corroborate the local findings of "hanging gardens" under the Drescher Inlet shelf-ice with a regional survey on sub-shelf-ice biota in the eastern and southern Weddell Sea in relation to the environmental conditions governing these upside-down filter-feeding communities.

Data management

Data will be made available in PANGAEA.

References

Arntz WE, Brey T, Gallardo VA (1994) Antarctic zoobenthos. Oceanography and Marine Biology: an Annual Review, 32, 241-304.

Clarke A, Aronson RB, Crame JA, Gili JM, Blake DB (2004) Evolution and diversity of the benthic fauna of the Southern Ocean continental shelf. Antarctic Science, 16(4), 559-568.

Gerdes D, Isla E, Knust R, Mintenbeck K, Rossi S (2008) Response of Antarctic benthic communities to disturbance: first results from the artificial Benthic Disturbance Experiment on the eastern Weddell Sea Shelf, Antarctica. Polar Biology, 31(12), 1469-1480.

Glud RN (2008) Oxygen dynamics of marine sediments. Marine Biology Research, 4, 243-289.

Voß J (1988) Zoogeographie und Gemeinschaftsanalyse des Makrozoobenthos des Weddellmeeres (Antarktis). Berichte zur Polarforschung, 45.

13. MARINE GEOLOGY

Hannes Grobe[1], Marcus Gutjahr[2], Maria-Elena Vorrath[1], Huang Huang[2,3]
Juliane Müller[1] Gerhard Kuhn[1] (not on board)

[1]AWI
[2]GEOMAR
[3]Uni Kiel

Background and Objectives

Past and ongoing geoscientific and oceanographic research in Antarctica's Weddell Sea sector has highlighted the key role of this area for influencing sea level, thermohaline circulation and climate at a global scale. However, scenarios of the possible contribution of ice-sheet melting to global sea-level rise and of past and future changes in water-mass circulation are mainly based on numerical models or reconstructions from far-field data because proximal evidence from the Weddell Sea embayment is sparse. Geological samples obtained in the study area will provide the base for reconstructing and dating direct changes (i.e. advance/retreat phases) of the Ronne and Filchner Ice Shelf during past (natural) climate fluctuations. These sediments further permit the identification of feedbacks between changes in sea ice coverage and the formation of deep-water in the Weddell Sea, which has a significant impact on global ocean circulation patterns. These data ultimately help to improve the performance and reliability of climate models. Water column samples and surface sediments will be used for calibration studies, while longer sediment cores will provide paleoceanographic records.

Particular focus is set on three main geochemical scientific aspects and one glacial-geomorphological and sedimentological investigation: First, further development of an organic geochemical approach using specific biomarker lipids (highly branched isoprenoids; IPSO25; Belt et al., 2016) is conducted as a tool for Antarctic sea ice reconstructions. Secondly, part of the expedition porgramme targets at the application of a new stable and radiogenic isotope analysis approach for the assessment of the discharge of continental ice into the Weddell Sea. Sampling of continental basal ice in coastal areas (which requires helicopter operations) will help to improve our knowledge on small-scale glacial weathering aspects and lithogenic particle transport to shelf sites within the Weddell Sea. Besides these Antarctic basal ice analyses, Weddell Sea shelf bottom water above multi core sediment sampling sites will be compared with the underlying sediment for its chemical and isotopic composition. Sediments will be sub-sampled aiming to distinguish the isotope geochemical signature of (i) the extracted porewater, (ii) the sedimentary authigenic (i.e. adsorbed) as well as (iii) terrigenous fraction. Isotope systems to be employed comprise iron (Fe), neodymium (Nd) and lead (Pb). Elemental abundances will be determined on a suite of major and trace elements across the periodic table. Taken together, results from these experiments will provide an assessment of how Antarctic runoff and sedimentary isotopic signatures are incorporated into the adsorbed fraction of Antarctic sediments. As part of these analyses, we aim to assess small-scale dissolved boundary fluxes across the sediment-bottom water interface in order to better constrain the cycling of these major and trace metals in the extreme Antarctic shelf environment. Finally, as a third major aim, water samples will be collected from various places in the southern Weddell Sea. Strikingly, this remote part of the Southern Ocean has to date not been sampled at all for its Nd and hafnium (Hf) isotopic composition (cf. Rickli et al., 2014), although the Weddell Sea is one of few key regions of Antarctic Bottom Water formation. Any water sample obtained from this region will provide invaluable new isotopic information for an increasingly used water mass tracer (van de Flierdt et al., 2016).

For geological studies, bathymetry data can moreover provide valuable information on the glacial history of an area by revealing the geomorphology of the seafloor, i.e. sub- and proglacial bedforms. Supplementing the bathymetric data, high resolution sub-bottom data provide information on the top 10s of meters below the seafloor and the lateral extension of sediment successions. By providing information on the geological architectures, the sub-bottom information can be used for paleoceanograpic and sedimentologic studies. Glacial-induced seabed features such as Mega-Scale Glacial Lineation (MSGL), Grounding Zone Wedges (GZW), moraines, and drumlins provide information on past ice sheet extents and if dated by sediment cores valuable data for palaeoclimate reconstructions (Hillenbrand et al., 2014).

Work at sea

Water column samples for Nd and Hf isotopic analyses and surface sediments will be collected by means of the CTD rosette and a multicorer (MUC), respectively. Ideally, separate water sampling will be carried out at two locations following trace metal clean water sampling protocols for Pb isotope and other transition metal abundance analyses using GoFlo bottles. Sedimentary porewaters obtained from MUC sampling will also be processed following trace metal clean sampling protocols allowing for the reliable determination of Fe and Pb isotope compositions, as well as transition metal concentrations. If applicable, the giant box corer will be used as well. Longer sediment cores will be obtained using the gravity corer. Sampling of the MUCs (1 cm slices) into combusted glass vials (biomarker) and Whirlpack sampling bags (sedimentology, micropaleontology) will take place onboard. Trace metal-clean sampling will be carried out under protected argon atmosphere in glove boxes. Sedimentary porewater samples will be sampled, centrifuged and extracted onboard. Samples designated for biomarker studies at home laboratories at AWI need to be stored frozen (-20°C). Surface sediment samples from areas where ice platelets occur (at ice shelf edges) will be sampled for ikaites (handled and stored anytime below +4°C). Gravity cores will be cut into 1 m sections and stored at 4°C. Water samples will be filtered on board, acidified and subsequently co-precipitated. Basal ice samples will be stored at -20°C after collection in dedicated trace metal clean containers and transported to GEOMAR Kiel for further processing in the clean lab facilities.

Expected results

Distribution of sedimentological parameter in the Weddell Sea is a dataset from 30 years of sampling with box corer and multicorer. This dataset will be extended in remote areas. Analytical parameters include organic carbon and carbonate, clay mineralogy, grain size distribution and microfossil content.

Data management

Data will be stored in PANGAEA and will be public available after a moratorium period of 3 years.

References

Belt ST, Smik L, Brown TA, Kim JH, Rowland SJ, Allen CS, Gal JK, Shin KH, Lee JI, Taylor KWR (2016) Source identification and distribution reveals the potential of the geochemical Antarctic sea ice proxy IPSO25. Nature Communications, 7, p. 12655.

Rickli J, Gutjahr M, Vance D, Fischer-Gödde M, Hillenbrand C-D, Kuhn G (2014) Neodymium and hafnium boundary contributions to seawater along the West Antarctic continental margin. Earth and Planetary Science Letters, 394, 99-110.

van de Flierdt T, Griffiths AM, Lambelet M, Little SH, Stichel T, Wilson DJ (2016) Neodymium in the oceans: a global database, a regional comparison and implications for palaeoceanographic research. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 374.

Hillenbrand C-D, Bentley MJ, Stolldorf TD, Hein AS, Kuhn G, Graham AGC, Fogwill CJ, Kristoffersen Y, Smith JA, Anderson JB, Larter RD, Melles M, Hodgson DA, Mulvaney R, Sugden DE (2014) Reconstruction of changes in the Weddell Sea sector of the Antarctic Ice Sheet since the Last Glacial Maximum. Quaternary Science Reviews 100, 111-136.

14. MICROPLASTICS - A POTENTIAL THREAT TO THE REMOTE AND PRISTINE ECOSYSTEMS OF THE ANTARCTIC SEAS?

Thomas Mani,[1]
Patricia Burkhardt-Holm[1], Helmut Segner[2], Markus Zennegg[3], Linda Amaral-Zettler (not on board)

[1]Uni Basel
[2]University of Bern
[3]EMPA
[4]NIOZ

Objectives

Microplastics (MP) pose an emerging threat to the global environment. Wherever one searches, MP is found, albeit in differing concentrations and constitutions. The Southern Ocean around Antarctica is thought to be an exception because it is considered beyond the reach of human impact. Furthermore, the major current systems of the Southern Ocean are thought to provide an effective barrier against the transfer of MP from lower latitudes to the Antarctic Ocean. However, very recent studies indicate that MP is present in the Southern Ocean. This highlights an urgent need for investigations into the possible origin and fate of MP: concentrations and distributions in the Southern Ocean, sources originating in Antarctica, and, finally, potential transfer into Antarctic food webs.

This project will explore MP occurrence and distribution in water and biota such as zooplankton and fish. To obtain insights into the origins and impacts of MP, we will study the microbial community composition on the plastic particles, as well as the persistent organic pollutant (POP) load of MP. To structure the research, we address these hypotheses: (1) The concentration of MP is higher in the more anthropogenically-exposed Western Antarctic Peninsula (WAP) and Scotia Sea than in the Weddell Sea (WS; remote from anthropogenic activities); (2) MP in the Southern Ocean around Antarctica originates from outside the ACC, i.e. north of the Polar front; (3) MP from local sources, i.e. research stations, and research and cruise vessels, contribute detectably to the MP load; (4) Microbial colonization of MP can inform MP origins; (5) The abiotic polymer characteristics (particle morphology, polymer type) and the POP profile of MP in the Southern Ocean around Antarctica reflect the characteristics of their sources; and, (6) Microplastic particles will enter Antarctic food webs. To reach the goals, we will sample MP in the water column, in filter-feeding zooplankton and fish of the different sites in the Southern Ocean (WS, WAP, Scotia Sea) and compare them with selected samples from subtropical southern gyres; we will characterize the MP particles with respect to their morphology, their polymer composition, the profile of adsorbed POPs and of the resident microbial communities. The microbiome work will include molecular analyses, as well as novel microscopic characterization using multiple probes combined with spectral analysis to unravel the spatial organization of the microbial communities. The polymer analysis will comprise ATR-FTIR and microscopic FTIR. Both approaches will contribute to assessing the importance of local sources (e.g. waste water treatment plants) and their potential origin from sites outside the ACC. The results will provide critical empirical data for ocean circulation transport models to backtrack the origin of floating MP based on probabilistic models of surface flow in the Southern Ocean. Our ultimate goal is to answer questions on the concentration and distribution of MP in the Southern Ocean, its potential sources and its uptake into the food web.

Work at sea

Water will be sampled for MP with a Manta Trawl and/or by filtering the water column via pumping sea water from beneath the vessels (approx. 12 m depth). The MP collected will be analyzed for particle morphology, POP and Plastisphere microbial community characterizations.

In addition, water for comparative microbial profiling (surrounding sea water vs. MP) will be sampled with a bucket or niskin bottle or CTD. If particles conspicuously appear to be plastic as determined by eye (e.g. based on color or shape), these will be analyzed for microbial community composition first and subsequently identified using FTIR.

Manta Trawl

A surface-trawling plankton net will be used to collect MP in surface water samples and towed at the surface. The manta trawl (aperture: 60 cm × 18 cm) will be equipped with a 333 µm mesh net and a removable cod end, as well as a mechanical flowmeter. The manta trawl (≈ 15 kg) will be deployed by an on-board automatic crane, as well as a steel rope and karabiner long enough to allow for a flat sampling angle (≤ 30°) at the side of the ship, outside the wake. Four to 20 tows of 5 km each with a tow speed of min. 0.5 m/s (technical lower limit mechanical flowmeter) to max. 4 m/s will result in approximately 540 m^3 of filtered seawater per sample and a potential total of 10,800 m^3. A flowmeter will be employed at the center of the Manta opening to quantify the sampled surface area and volume (volume Manta 0.108 m^3). After every tow the Manta will be hauled from the water and the content of the removable cod end will be rinsed into Bogorov counting chambers using 0.22-µm filtered seawater. Conspicuous particles will be sorted and characterized microscopically.

MP from pumped water

To address the MP load of water samples, we sample surface waters by using on-board pumps (seawater pumps of *Polarstern*). The water will be filtered onto 10 µm stainless steel meshes. The meshes will be stored frozen for later polymer analysis in the laboratory. MP collected in this way may be challenging to extract DNA from, so a subset of samples will be preserved instead for CLASI-FISH community visualization. Samples for microscopy via FISH and CLASI-FISH will be fixed in paraformaldehyde (for less than 24 hours) then transferred to 50 % ethanol in PBS for storage at -20°C.

To compare free-living microbial communities with those on MP, we will filter 2-4 L by drawing water from below or at the surface via bucket or niskin bottle, through a 0.2 µm Sterivex™ cartridge filter (Millipore) to collect microorganisms suspended in the ambient surface water and then flood the filters with 2.0 ml of PureGene lysis buffer.

Expected results

We expect to find small amounts of microplastics, which will be characterized microscopically on board and elaborated characterization using FT-IR will follow in the home laboratory at University of Basel and at AWI, Helgoland. Microplastic particles for sequencing of microbial communities, as well as samples of free-living communities will be collected, stored and transferred to the home laboratory at NIOZ.

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. All sequence data will be deposited in EBI's European Nucleotide Archive and will conform to the minimum information standards recommended by the Genomics Standards Consortium (http://gensc.org/projects/mixs-gsc-project/).

15. PROJECT ISO-ARC: ISOTOPE SIGNATURE OF WATER VAPOUR OVER THE SOUTHERN ATLANTIC OCEAN

Martin Werner[1]

[1]AWI

Objectives

Within the project Iso-Arc, funded by AWI's strategy fond, water vapour and its isotopic signature ($H_2^{18}O$ and HDO) have been continuously measured on board of *Polarstern* since mid-2015. These measurements are accompanied by daily surface water sampling. In combination with corresponding water isotope measurements at *Neumayer III* station (since early 2017) and paired with complementing climate simulations, an integrated analyses of model results and measurements will allow a quantitative assessment of the Southern Atlantic water cycle, its isotopic variations and imprint in Antarctic ice core records.

Work at sea

Vapour isotope measurements on board of *Polarstern* are performed by a light-weighted cavity-ring-down spectrometer (CRDS, built by Picarro Inc.). The CRDS system runs continuously and autonomously, and requires only a few minutes of daily maintenance. However, during the first days of PS111, additional measurements and data analyses will be carried out, focussing on two different aspects:

- data acquisition of $H_2^{17}O$ in vapour, which has not been studied on previous PS cruises;
- in-detail detection of isotope variability in dependence of sea ice coverage. Previous analyses have revealed that the later is an important aspect for an improved understand and modelling of water vapour isotopes in polar regions.

Expected results

From our work at sea, we will get a first assessment on the quality of the performed $H_2^{17}O$ measurements in vapour and its potential future utilization. The observation of isotopic changes in partly or fully covered sea ice areas will help to evaluate its current modelling approach.

Data management

All humidity and isotope data of this project will be uploaded to the PANGAEA database after processing and post-operative calibration. Unrestricted access to the data will be granted within 2-3 years, pending analysis and publication.

16. TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

	Name
AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
BAS	British Antarctic Survey , Cambridge High Cross, Madingley Road Cambridge, CB3 0ET UK
DWD	Deutscher Wetterdienst Geschäftsbereich Wettervorhersage Seeschifffahrtsberatung Bernhard Nocht Str. 76 20359 Hamburg Germany
GEOMAR	GEOMAR Helmholtz-Zentrum für Ozeanforschung Wischhofstr. 1-3 24148 Kiel Germany
LIO	Leibniz Institut für Ostseeforschung Säest. 15 18199 Rostock Germany
MGU	Universität Basel, MGU Vesalgasse 1 4051 Basel Schweiz

	Name
MRI	Mammal Research Institute Dept. of Zoology & Entomology Universität of Pretoria Private Bay X20, Hatfield 0028 Gauteng South Africa
NIOZ	NIOZ Royal Netherlands Institute for Sea Research Korringa Weg 7 4401 NT Yerseke Niederlande
NOC	National Oceanographic Centre, Southampton European Way Southampton, SO14 3ZH UK
PIK	Potsdam-Institut für Klimafolgenforschung Telegrafenberg A62 14473 Potsdam Germany
Uni Barcelona	Facultat de Ciencias Environmental Sciences Universita Autonoma de Barcelona Barcelona, Bellaterra Spain
Uni Bergen	Uni Research Climate P.O. Box 7810 5020 Bergen Norway
Uni Bremen	Universität Bremen Geowissenschaften Bibliotheksstr. 1 28359 Bremen Germany
Uni Bremen, IU	Universität Bremen Institut für Umweltphysik Otto-Hahn-Allee 28359 Bremen Germany

	Name
Uni Kiel, Zoologie	Universität Kiel Zoologisches Institut Am Botanischen Garten1-9 24118 Kiel Germany
Uni Trier	Universität Trier Fachbereich VI - Raum- und Umweltwissenschaften Fach Umweltmeteorologie D-54286 Trier Germany

17. TEILNEHMER / PARTICIPANTS

No.	Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Scientific Field
1	Arndt	Jan Erik	AWI	Scientist	Geophysic
2	Arndt	Stefanie	AWI	Scientist	Sea ice physics
3*	Bartsch	Christine	AWI	Physician	Logistics
4	Bester	Marthan	MRI Uni Pretoria, RSA	Scientist	Biology, zoology
5	Bornemann	Horst	AWI	Scientist	Biology, zoology
6	Braakmann-Folgmann	Anne	AWI	Student	Geophysics
7	Diego Feliu	Marc	Uni, Barcelona, Spain	Phd Student	Environm.sci.
8	Geilen	Johanna	Uni Freiburg, AWI	Student.	Environm.phys
9	Grobe	Hannes	AWI	Scientist	Geology
10	Gutjahr	Marcus	GEOMAR, Kiel	Scientist	Geochemistry
11	Hanfland	Claudia	AWI	Scientist	Geochemistry
12	Heins	Lena	AWI	Student	Biology
13	Hellmer	Hartmut	AWI	Scientist	Oceanography
14*	Hirsekorn	Marius	AWI	Engineer	Logistics
15	Horb	Stanislav	Uni Kiel, Zoologie	Scientist	Zoology
16	Huang	Huang	Uni Kiel, GEOMAR,	Phd Student	Geochemistry
17	Huntemann	Marcus	Uni Bremen, AWI	Scientist	Sea ice physics
18	Janout	Markus	AWI	Scientist	Oceanography
19	Jenkins	Adrian	BAS, Cambridge, UK	Scientist	Geophysics
20	Jürgens	Klaus	LIO Warnemünde	Scientist	Microbiology
21	Kern	Yannick	AWI, Uni Bergen, N	Student	Oceanography
22	Lischka	Silke	GEOMAR, Kiel	Scientist	Biology
23	Maier	Sandra	AWI, NIOZ, NL	Phd Student	Biology
24	Mani	Thomas	MGU Uni Basel, CH	Phd Student	Geography
25	McPhail	Stephen	NOC Southampton, UK	Engineer	Electronics, AUV
26	Meeske	Christian	LIO Warnemünde	Engineer	Biology
27	Michels	Jan	Uni Kiel, Zoologie	Scientist	Biology, zoology
28	Osterhus	Svein	Uni Research-climate, Bergen, N	Scientist	Oceanography
29	Owsianowski	Nils	AWI	Engineer	Biology, ROV
30	Reese	Ronja	PIK Potsdam	Phd Student	Sea ice physics
31	Reiser	Fabian	Uni Trier, Environm.Meteor.	Phd Student	Meteorology
32	Richter	Claudio	AWI	Scientist	Biology
33	Schnaase	Frank	Uni Trier, Environm.Meteor.	Phd Student	Oceanography
34	Schröder	Henning	AWI	Engineer	Biology, ROV

No.	Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Scientific Field
35	Schröder	Michael	AWI	**Chief scientist**	Oceanography
36	Slabon	Patricia	AWI	Phd Student	Geosphysics
37	Stoll	Nicolas Angelo	AWI	Student	Sea ice physics
38	Stolle	Clara	Uni Kiel, AWI	Student	Oceanography
39	Sültenfuß	Jürgen	Uni Bremen	Scientist physics	
40	Sültenfuß	Pia	Uni Bremen, Uni Oldenburg	Student	Geoscience
41	Templeton	Robert	NOC Southampton, UK	Engineer	Mechanics, AUV
42	Vorrath	Maria-Elena	AWI	Phd Student	Geology
43	Wege	Mia	MRI Uni Pretoria, RSA	Scientist	Biology, zoology
44*	Werner	Martin	AWI	Scientist	Physics
45	Winkelmann	Ricarda	PIK Potsdam	Scientist	Sea ice physics
46	Wischnewski	Fanny	Uni Bremen	Student	Physics
47	Wisotzki	Andreas	AWI	Scientist	Oceanography
48*	Wurr	Karsten	AWI	Director	Board of Directors
49	Vaupel	Lars	Heli Service Int.	Chief pilot	
50	Gischler	Michael	Heli Service Int.	Pilot	
51	Richter	Roland	Heli Service Int.	Technician,	Certifying staff
52	Rothenburg	Mark	Heli Service Int.	Technician	
53	Schaaf	Tobias	DWD	Scientist	Meteorology
54	Rohleder	Christian	DWD	Technician,	Meteorology

3* Christine Bartsch nur bis Neumayer
44* Martin Werner nur bis Neumayer
48* Karsten Wurr nur bis Neumayer
14* Marius Hirsekorn erst ab Neumayer

18. SCHIFFSBESSATZUNG / SHIP'S CREW

	Name	Rank
1.	Schwarze, Stefan	Master
2.	Grundmann, Uwe	1.Offc.
3.	Farysch, Bernd	Ch. Eng.
4.	Langhinrichs, Moritz	EO Ladung
5.	Fallei, Holger	2.Offc.
6.	Neumann, Ralph Peter	2.Offc.
7.	Rudde-Teufel	Doctor
8.	Dr. Hofmann, Jörg	Comm.Offc.
9.	Grafe, Jens	2.Eng.
10.	Krinfeld, Oleksandr	2.Eng.
11.	Haack, Michael	2. Eng.
12.	Redmer, Jens Dirk	Elec.Techn
13.	Ganter, Armin	Electron.
14.	Hüttebräucker, Olaf	Electron.
15.	Nasis, Ilias	Electron.
16.	Himmel,Frank	Electron
17.	Loidl, Reiner	Boatsw.
18.	Reise, Lutz	Carpenter
19.	Hagemann, Manfred	A.B.
20.	Winkler, Michael	A.B.
21.	Scheel, Sebastian	A.B.
22.	Bäcker, Andreas	A.B.
23.	Brück, Sebastian	A.B.
24.	Wende, Uwe	A.B.
25.	Klee, Philipp	A.B.
26.	Löscher, Steffen Andreas	A.B.
27.	Preußner, Jörg	Storek.
28.	Teichert, Uwe	Mot-man
29.	Rhau, Lars-Peter	Mot-man
30.	Lamm, Gerd	Mot-man
31.	Schünemann, Mario	Mot-man
32.	Schwarz, Uwe	Mot-man
33.	Schnieder, Sven	Cook
34.	Silinski, Frank	Cooksmate
35.	Möller, Wolfgang	Cooksmate
36.	Czyborra, Bärbel	1.Stwdess
37.	Wöckener, Martina	Stwdss/KS

	Name	Rank
38.	Dibenau, Torsten	2.Steward
39.	Silinski, Carmen	2.Stwdess
40.	Golla, Gerald	2.Steward
41.	Arendt, Rene	2.Steward
42.	Sun, Yong Shen	2.Steward
43.	Chen, Dan Sheng	Laundrym.