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

EXPEDITION PROGRAMME PS118

Polarstern

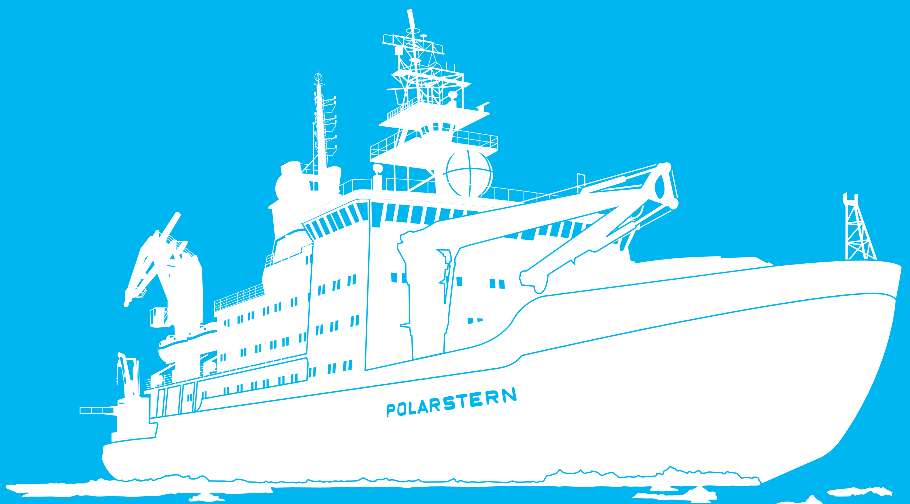
PS118

Punta Arenas – Punta Arenas

9 February 2019 - 10 April 2019

Coordinator: Rainer Knust

Chief Scientists: Boris Dorschel



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LARSEN

Chief Scientist
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1. EINLEITUNG

Boris Dorschel, Alfred-Wegener-Institut

Die Antarktische Halbinsel ist eine der sich am schnellsten erwärmenden Regionen dieser Welt (Bentley et al. 2009; Rignot et al. 2008; Scambos et al. 2000; Vaughan et al. 2003). Als mögliche Folge sind in den Jahren 1995 und 2002 erst der Larsen A Eisschelf und später der Larsen B Eisschelf fast vollständig zerfallen (De Angelis and Skvarca 2003; Domack et al. 2005; Gutt et al. 2011; Pudsey et al. 2001; Rebesco et al. 2014; Rott et al. 1996; Shepherd et al. 2003; Skvarca and De Angelis, 2003; Wendel and Kumar, 2017). Dadurch verbleibt nur noch der Larsen C Eisschelf als letzter großer Eisschelf im westlichen Weddellmeer. Im Juli 2017 hat der Larsen C Eisschelf den Eisberg A-68 gekalbt. Mit ca. 5.800 km2 ist A-68 einer der größten Eisberge, die jemals erfasst worden sind (Abb. 1).

Durch den Abbruch von A-68 hat sich die Schelfeiskante landwärts verlagert. Dieser Rückzug der Schelfeiskante hat einen erheblichen Einfluss auf die Umweltfaktoren und Ökosysteme in dem ehemals vom Schelfeis bedeckten Gebiet. Durch den Eisschelf war dieses Gebiet von der Atmosphäre und dem Einfluss von Sonnenlicht entkoppelt. In Folge der Veränderungen kommt es nun zu Austauschprozessen zwischen Ozean und Atmosphäre und zur Primärproduktion in der oberen Wassersäule in dem Gebiet das vormals von A-68 bedeckt gewesen ist. Diese Veränderungen finden in einem sehr kurzen Zeitraum statt, was die Ökosysteme zwingt, sehr schnell zu reagieren und sich anzupassen. Um die Veränderungen, Anpassungsmechanismen und Widerstandsfähigkeit der Ökosysteme infolge derartig abrupter Veränderungen zu verstehen, ist es nötig, möglichst früh Basisparameter für Umweltfaktoren und biologische Prozesse zu erfassen. Diese beschreiben auch den Ursprungszustand für spätere Wiederholungsuntersuchungen. Auf Grund der Abgeschiedenheit gibt es derzeit nur begrenzt wissenschaftliche Daten aus dem Gebiet von Larsen A und B., Larsen C ist fast vollständig unerforscht. Die Expedition PS118 mit *Polarstern* ist daher sehr interdisziplinär angelegt mit dem Ziel, möglichst viele Grundlageninformationen zu erfassen.

Ein Arbeitsschwerpunkt für PS118 ist die Erfassung von Daten, die zu einem besseren Verständnis von Umweltprozessen und biologischen Prozessen im Zusammenhang mit dem Rückzug eines Eisschelfes führen. Des Weiteren sollen Daten vom wenig untersuchten Larsen C Kontinentalschelf und –hang gewonnen werden.

Folgende übergeordnete Forschungsgebiete sollen während PS118 bearbeitet werden: Eisschilddynamik, Ozean – Cryosphärenwechselwirkungen, Ozeanzirkulation und eine Vielzahl biologischer und Umweltprozesse, wie z.B. die Funktion von Ökosystemen, Habitatverteilungen, Populationsdynamiken und -verbreitungen. Diese Diversität und Disziplinen wird auch durch 13 Arbeitsgruppen an Bord widergespiegelt. Sie kommen aus den Wissenschaftsbereichen Bathymetrie/Hydroakustik, Biologie, Geologie, Geophysik, Ozeanographie und Meereisphysik. Außerdem wird eine Person an Bord Filmaufnahmen für eine TV-Dokumentation aufnehmen.

Expedition PS118 mit *Polarstern* beginnt am 9. Februar 2019 in Punta Arenas (Chile) und endet am 10. April 2019 ebenfalls in Punta Arenas. Das Hauptzielgebiet der Expedition ist der Larsen C Schelf. Durch den Abbruch von A-68 ist das kürzlich von Eisschelf befreite Gebiet vor dem Larsen C Eisschelf ein zusätzliches Interessengebiet für PS118 geworden. Weitere Zielgebiete sind die vormals von den Larsen A und B Eisschelfen bedeckten Bereiche und eine Region des Larsen Kontinentalhangs die von tiefen Canyons durchzogen ist. Das alternative Arbeitsgebiet umfasst das Powell- und das Janebecken (Abb. 1).

SUMMARY AND ITINERARY

The Antarctic Peninsula is among the fastest warming regions of the world (Bentley et al. 2009; Rignot et al. 2008; Scambos et al. 2000; Vaughan et al. 2003). In 1995, the Larsen A ice shelf and in the 2002 Larsen B ice shelf disintegrated almost entirely leaving the Larsen C ice shelf as the last remaining ice shelf in the west Weddell Sea (De Angelis and Skvarca, 2003; Domack et al. 2005; Gutt et al. 2011; Pudsey et al. 2001; Rebesco et al. 2014; Rott et al. 1996; Shepherd et al. 2003; Skvarca and De Angelis, 2003; Wendel and Kumar, 2017). In July 2017, Larsen C ice shelf calved iceberg A-68. With ca. 5,800 km2, A-68 is one of the largest icebergs ever recorded (Fig. 1) resulting in a significant retreat of the front of the Larsen C ice shelf. This retreat has profound influences on the environmental settings and ecosystems in the area that was previously covered by the ice shelve. Until recently, these areas were decoupled from the atmosphere and the impact of sunlight. Now they are experiencing ocean atmosphere exchange processes and primary production in the surface waters. These significant changes happen in a very short time period, forcing the ecosystems to quickly respond to the new environmental conditions. To understand the adaptation mechanisms and the resilience of ecosystems to these abrupt changes, it is necessary to collect base-line information on environmental and biological processes. Also for later repetitive studies, this baseline information is important. So far, only limited information is available from the Larsen A and B area and, due to its remoteness, hardly any information exist from the Larsen C area. Expedition PS118 with *Polarstern* to the Larsen shelf area is a multidisciplinary approach with the aim to collect as many data sets as possible.

One focus of PS118 is to collect information towards the understanding of the environmental and biological processes associated with ice shelf break-ups. In addition, data will be collected from the understudied Larsen shelf and slope. Data collection during PS118 is designed to answer overarching questions regarding ice sheet dynamics, ocean – cryosphere interactions, ocean circulation and a variety of biological and environmental processes including ecosystem functioning, habitat distribution and population dynamics and distributions. This diversity in disciplines is also represented from a total of 13 working groups on board. They cover the disciplines of bathymetry/hydroacoustic, biology, geology, geophysics, oceanography, and sea ice physics. Furthermore, one person will be on board for a TV documentary.

Expedition PS118 with *Polarstern* will commence in Punta Arenas (Chile) on the 9th of February 2019 and will end in Punta Arenas (Chile) on the 10th of April 2019. The expedition targets the Larsen C shelf. Due to the recent break-up of the giant iceberg A-68 from Larsen C ice shelf, the newly exposed seabed, previously covered by A-68, has become an additional target area for PS118. Further study areas are the former Larsen A and B ice shelves and an area of the Larsen continental slope that is deeply incised by canyons. The alternative working area covers the Powell and the Jane basin (Fig. 1).

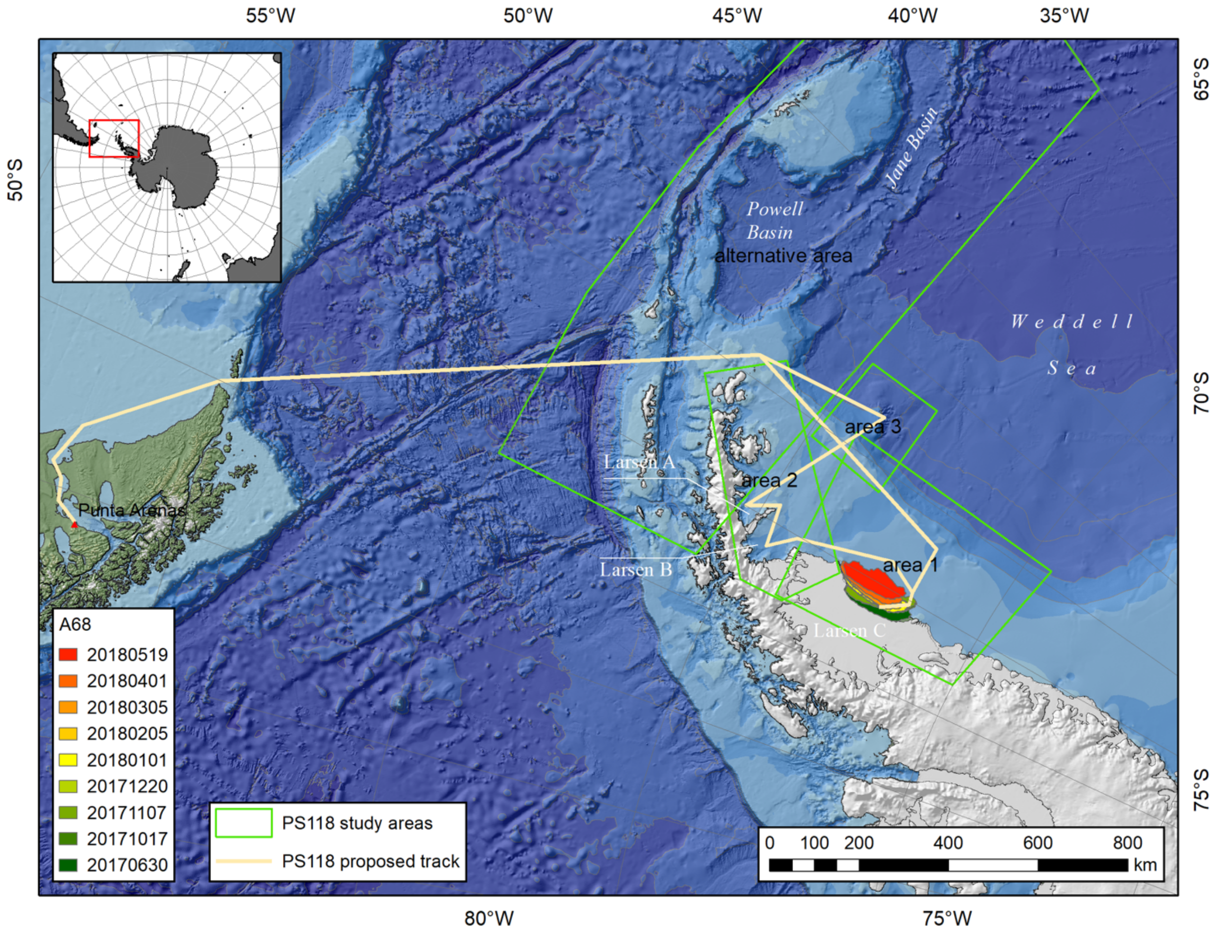

Abb. 1: Übersichtskarte über das Arbeitsgebiet der Expedition PS118 mit Polarstern (9. Februar 2019 bis 10. April 2019).

Fig. 1: Overview of the study area of expedition PS118 with Polarstern (9th of February 2019 until 10th of April 2019).

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2. MACROBENTHIC BIODIVERSITY UNDER ANTARCTIC ICE-SHELVES - YEAR-1 ASSESSMENT OF THE SEABED EXPOSED BY THE 2017 CALVING OF THE LARSEN C ICE SHELF

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Objectives

On 12 July 2017, the Larsen-C Ice Shelf calved the largest iceberg originating from the Antarctic Peninsula ever recorded (Hogg & Gudmundsen 2017). As iceberg A-68 moves north, it will leave an area of 5,800 km2 of seabed newly exposed to open marine conditions. Much of this area has very likely remained ice-covered for centuries and may have been covered since the last inter-glacial (<100kyr) period. The calving of A-68 offers a unique scientific opportunity for fundamental research to address questions around the mobility and colonisation capacity of benthic marine species. Our proposed work on the macrobenthic fauna using the C-EBS is complementary to the biological and ecological work in the Hauptantrag proposed by Richter and Piepenburg. To date the benthic work in the Larsen-A&B areas by the AWI and the US-lead LARISSA project were conducted by remote operated vehicle (ROV), Agassiz trawl (AGT), and multicorer (MUC) (Hauquier et al. 2016; Gutt et al. 2011; Fillinger et al. 2013) and the biological work proposed for PS118 is using the same equipment to be comparable with previous work. While the first two types of equipment are documenting and collecting primarily megafauna, the MUC collects predominantly infauna of the meio- and macrobenthic size but not the supra- and epibenthic macrofauna. Our use of the C-EBS with 0.5 mm mesh-size nets will collect an important, highly diverse and abundant fraction of the benthic biodiversity, which is important for addressing rarity and commonness in marine ecosystems (Connolly et al. 2014). The macrofauna collected by C-EBS contains small sized macrofauna species as well as the juvenile stages of larger, megafaunal species that can be collected or seen by AGT and ROV and are likely to be missed as juveniles. As presence of these juveniles is important for studies documenting colonisation and succession of Larsen-C, we see our proposed project as an important addition to the “Hauptantrag”.

Our previous work on the Antarctic macrobenthos from the continental shelf to the abyssal has shown the importance of these faunal fractions for the assessment of biodiversity, biogeography, phylogenetics and ecology (e.g. Brandt et al. 2007, 2014; Kaiser et al. 2008; Linse et al. 2002; Kaiser et al. 2008; Neal et al. 2014; Raupach et al. 2007) . Especially in the evaluation of species richness in taxa such as polychaetes, crustaceans and molluscs, samples collected by EBS have significantly advanced global knowledge (Brandt et al. 2016). The biodiversity and assemblage structure results collected from the C-EBS would be directly comparable to published research on polychaetes, isopods, cumaceans, bivalves, gastropods and sponges from the SO deep sea, the Amundsen, Weddell and Ross seas, with unpublished BAS data from the Filchner Trough, Prince Gustav Channel and the South Orkney shelf.

Investigating the seabed under the recently calved A-68 offers a unique and short-lived opportunity to sample former under-ice-shelf communities, providing a baseline against which to follow their succession via future grant applications. Our project on the macrofauna will therefore address questions relating to the sustainability of Antarctic continental shelves communities and biodiversity under climate change, the processes by which benthic populations migrate, and the degree to which the distribution of marine benthos can be used to interpret past responses to climate change in various systems (e.g. the Antarctic ice sheet itself). Our governing hypothesis is: H: “Until the calving of the Larsen-C iceberg, A-68, the benthic fauna on the seabed beneath ice shelf has likely comprised oligotrophic assemblages resembling deep-sea Weddell Sea assemblages. The calving of A-68, and the exposure of the seabed it covered to open-marine and sea-ice conditions will initiate a rapid colonisation by new species that will transform the benthic ecosystem significantly within 3-5 years.”

Objective 1: Biodiversity and assemblage structure assessment of the epi- and suprabenthic macrofauna.

Approach: Sample and characterize macrofaunal biodiversity in the benthic community below A-68; Faunal collection and appropriate sample fixation for taxonomic identification. Characterisation of assemblages formerly covered under A-68 and their spatial distribution at a range of scales in relation to distance from the former ice front. Faunal community analysis from video imagery with taxonomic identification validated with physical specimen samples.

Objective 2: Taxonomic descriptions of the selected macrobenthic species discovered in the Larsen-C area and their phylogeography.

Approach: Identification of sampled C-EBS macrofauna to morphospecies level and in selected taxa use of integrative taxonomy (morphology and molecular genetics where necessary) for taxonomic descriptions. Biogeographic analysis of key faunal elements, e.g. isopods, bivalves and gastropods, using distribution data records from OBIS, GBIF and own literature databases. Molecular phylogenetics and phylogeographic analyses of selected taxa using COI, 16S, 28S and 18S gene sequences.

Objective 3: Comparison of Larsen-C Year-1 biodiversity and assemblage structure with other areas in the influence of the Weddell Gyre to investigate turn-over, colonisation and/or succession.

Approach: Biological and environmental data will be analysed with multivariate statistics and compared to assemblages and ecosystems reported from the SO shelf, slope and deep-sea, especially those from the Prince Gustav Channel, Larsen-A/B, Filchner Trough, and the bathyal and abyssal Weddell Sea.

Objective 4: Reporting results to CCAMLR as scientific support of CCAMLR measure 24-04.

Approach: Biological and environmental data will be reported to CCAMLR in support of the need to maintain protection of the area revealed by the calving of A-68. The present protection designation, lasting 10 years or potentially longer will rely upon results from the scientific community. With such a unique opportunity, the scientific community can address questions relating to the sustainability of Antarctic continental shelf communities and biodiversity under climate change, in the absence of fishing.

Work at sea

The C-EBS (Fig. 2) is a proven apparatus designed for sampling small epibenthic and suprabenthic macrofauna at any depth and on any substrate. The C-EBS is equipped with supra- and epi- benthic samplers of 1 m width and 33 cm height with attached plankton nets of 500 µm and a cod end of 300 µm as described by Brandt and Barthel (1995) and Brenke (2005). A mechanical opening-closing device prevents entry of pelagic fauna during heaving. Additionally, the EBS carries a deep-water camera system (DWCS) and a CTD which measures data on temperature, pressure and conductivity.

The BAS C-EBS to collect benthic macrofauna will mostly be deployed at the same locations as the benthic imagery (OFOBS), mega- (AGT) and meiofaunal (MUC) sampling systems. The epi- and suprabenthic macrofauna samples collected by the C-EBS will be used for studies on biodiversity, assemblage structure, biogeography, phylogenetics and phylogeography.

Pre-deployment the DWCS timer will be set that the video camera will start recording ~10 min before reaching the seabed, the lights and lasers will be started on deck. On deployment the C-EBS will be lowered to the seabed with a maximum of 60m/min veer rate until the cable length is 1.5 (>800m water depth)/ 2 (<800m water depth) times water depth. The C-EBS will be trawled for 10 min at 1kn along the seafloor. Then it will be hauled at 30m/min until the C-EBS is off the seabed and with C-EBS in the water column the haul rate is increased to 60m/min and the ship is steaming 0.3 kn.

The epi- and suprabenthic samplers recovered from the C-EBS will be visually screened on arrival back on deck, selected specimens hand-picked for genomic and food-web analyses (fixed in RNAlater or frozen at -80°C and -20°C) and the remaining sample asap in precooled -20°C ethanol for further biodiversity, genetic, and ecological analyses and stored at BAS and the Senckenberg Research. The 6l UN approved kegs containing the ethanol-fixed epi- and suprabenthic sampler and stored at -20°C will be rolled every 6h for 48h to allow proper fixation of the specimens in the sample. Afterwards the ethanol % in the kegs will be measured and if lower than 70 %, replaced with fresh ethanol to guarantee fixation for later molecular genetic work. After 48h the sorting of the sample will begin on board under stereomicroscopes. The samples will also be sorted to higher taxon level (e.g. class; Linse & Brandt during previous C-EBS expeditions sorted into 43 taxa on board) and later analyzed in detail in the home laboratories (determination to morphospecies level).

The video image files of the DWCS will be downloaded from the camera data-drives and shared with the expedition team. Between deployments, the camera, light and laser system will be checked and charged.

The CTD is attached to the C-EBS from about 1 m above the seafloor and therefore collects near-bottom temperature, salinity and conductivity data. These will be shared with the expedition team via *Polarstern's* data drives.

Fig. 2 BAS C-EBS with DWCS and CTD

Expected results

The expected results from each C-EBS deployment are macrobenthic biodiversity samples collected by the supra- and epibenthic samplers, *in-situ* video images and CTD files.

The C-EBS deployments will be listed in a table describing success of samplers, DWCS and CTD, with estimated sample volumes per sample, duration of collected video, and short description of substrate (soft sediment, sponge spicules mats, drop stones, boulders).

Further results will be preliminary data on the macrobenthic assemblage composition and abundance of selected stations at higher taxon level (phylum, class, order) resulting from the sample sorting. These data will be displayed in tables and on georeferenced pie-chart figures.

Data management

Metadata of the C-EBS deployments will be deposited in PANGAEA as part of the DSHIP-System on *Polarstern*. Biological C-EBS samples will be housed at BAS and at Senckenberg, there sorted into systematic groups and distributed to collaborating taxonomic experts. Taxonomic information (molecular barcode sequences, georeferenced location records, *in-situ* images) will be published in the relevant international databases, e.g. Genbank, OBIS and Deep-sea Imagery database. A report on the macrobenthic biology will be submitted to CCAMLR working groups and meetings via UK representative PI Trathan in summer and autumn 2019.

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3. DIPLONEMIDS: AN EMERGING MAJOR PLAYER AMONG PLANKTONIC MICROEUKARYOTES

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Objectives

Until recently, biodiversity of marine microeukaryotes (protists) remained understudied, as compared to that of bacteria and macroscopic organisms. This situation has changed with the advent of metabarcoding techniques, the development of universal eukaryotic primers and finding the most informative gene regions. Recent studies have mapped protist biodiversity on the global scale: de Vargas et al. (2015), Massana et al. (2015), Pernice et al. (2016), among others. A large set of metabarcodes (the V9 region of the 18S rRNA gene) was generated for planktonic eukaryotes by the Tara Oceans project (de Vargas et al. 2015). Unexpectedly, in that dataset diplonemids emerged among the most abundant and diverse (i.e. rich in operational taxonomic units, OTUs) clades of eukaryotes in the plankton. Diplonemids (Diplonemea) used to be a very small and obscure group of protists, belonging to the Euglenozoa phylum, alongside with much better studied kinetoplastids and euglenids. Diplonemids are marine heterotrophs of unknown lifestyle and include just few formally described genera (Tashyreva et al. 2018). We analyzed an extended Tara Oceans metabarcoding dataset (850 size-fractionated plankton communities sampled at 123 globally distributed sites) and revealed that diplonemids surpass all other eukaryotic phyla in diversity and are among the most abundant phyla in the mesopelagic zone (Flegontova et al. 2016). Members of by far the most diverse diplonemid family Eupelagonemidae (also known as deep-sea pelagic diplonemids or the DSPD I clade, Lara et al. 2009) remain uncultured, and their trophic mode remains unknown (Gawryluk et al. 2016). We believe that diplonemids experienced a relatively recent speciation burst, potentially via neutral speciation mechanisms (Suzuki and Chiba 2016), after entering a new ecological niche.

We plan to study biogeography and diversity of diplonemids and other microbial eukaryotes in the Southern Ocean. Based on our previous studies, we know that diplonemids are especially abundant in the mesopelagic and deeper layers, and that they range in size from about 1 to 20 µm. We plan to:

1. sample the bathypelagic zone (1,000-4,000 m), where diplonemids remain understudied;
2. construct detailed depth profiles (surface to bottom) by sampling nearby locations;
3. obtain independent estimates of relative abundance for diplonemids using the metabarcoding and fluorescent in situ hybridization (FISH) approaches.

Work at sea

We plan to collect up to 150 planktonic DNA samples of the 0.8-20 µm size fraction, from depths of 0-4,000 m. We plan to construct detailed depth profiles, by sampling 5 to 10 depths at nearby locations. In an ideal situation, we plan to take 4 water samples from Niskin bottles daily, 10 L per sample. Water will be filtered through a system of three filters (200 µm, 20 and 0.8 µm). The last (0.8 µm) filters will be preserved in a cell lysis buffer and stored at -20 °C. Metabarcoding approaches are prone to primer specificity biases, thus we also plan to collect up to 50 samples of fixed cells on 0.8 µm filters that would allow us to get independent estimates of diplonemid abundance using a specific oligonucleotide probe and a FISH method. Our work programme is flexible and would depend on the cruise program and the depth profile of the route.

Expected results

Taking advantage of an unpublished dataset combining samples of the Tara Oceans and Tara Polar Circle expeditions, we observed that diplonemids are especially abundant in the polar regions. The Tara project has sampled at 55 locations in the Arctic (unpublished data) and 9 locations in the Antarctic (de Vargas et al. 2015, Flegontova et al. 2016). Given the paucity of polar samples in our published studies (Flegontova et al. 2016, 2018), we have started a metabarcoding study focused on diplonemid diversity and biogeography in the polar regions. To this end, we collected mesopelagic samples at 38 locations in the Greenland and Norwegian Seas (the cruise AREX2016, Institute of Oceanology, Polish Academy of Sciences). We have already generated metabarcodes for the Arctic samples: for the shorter V9 region (about 130 nt in length) and for the longer V4 region of the 18S rRNA gene (up to 600 nt and longer). We aim to extend our dataset by sampling in the Southern Ocean and perform a comparative study of diplonemid diversity and biogeography in the polar regions.

For samples collected during the PS118 cruise, the V4 and V9 metabarcodes will be amplified with universal eukaryotic primers for all samples and sequenced using appropriate technologies and read length (Illumina HiSeq or MiSeq, paired reads up to 300 nt long). An

OTU delimitation approach and analysis pipeline tested in our previous studies will be used (Flegontova et al. 2016, 2018). Combining the Arctic dataset collected by us and the Antarctic dataset to be collected, we will perform a detailed investigation of diplonemid biodiversity in polar regions. Since community composition data would be generated using universal primers, diplonemids would be studied in the context of other eukaryotes. In summary, we plan to study this neglected but important group in the polar regions and in the bathypelagic zone, where it remains little explored so far. We hope that additional data on correlation of diplonemid abundance with environmental factors and on co-occurrence with other organisms will help us to propose hypotheses concerning their trophic strategy, which remains elusive do far. This piece of information is crucial for bringing diplonemids of the most important Eupelagonemidae family into culture, which would allow further studies of their biology.

Data management

Results of our project will be published in peer-reviewed journals. Sample information will be deposited at the PANGAEA database. Plankton samples on filters will be used for DNA extraction, and DNA will be stored at -70 °C at the Institute of Parasitology, Czech Academy of Sciences, and available upon request. All metabarcoding sequences (raw reads) generated during the project will be submitted to public databases: the European Nucleotide Archive and EukBank (unieuk.org), where they will be freely available.

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4. INTEGRATED MOLECULAR AND ISOTOPIC CHARACTERIZATION OF SOUTHERN OCEAN KEY TAXA: GENE FLOW, ADAPTATION, AND TROPHIC ECOLOGY OF BIRDS, FISH AND MACROINVERTEBRATES

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Objectives

The overall objectives of our research consortium are to improve the understanding of the distribution and (genetic and trophic) diversity of marine Antarctic fauna, and how these might change in the future. The Southern Ocean is productive and rich in biodiversity, but faces environmental changes that occur at unprecedented rates (see e.g. Gutt et al. 2014; Griffiths et al. 2017). Therefore, many organisms face the therefore challenge to either adapt or migrate to avoid extinction. Which option is feasible for specific species or populations depends on both abiotic and biotic factors. The latter includes traits that a species naturally exhibits, the potential to change these traits in a given population over time (adaptation) and the interplay between species for example through predation and competition. It is therefore important to assess biodiversity at all levels, that is from species to populations to ecosystems. We consequently focus on three types of analyses: 1) biodiversity census data at the species level, 2) genomic diversity at the population level, 3) trophic diversity at the ecosystem/community level. Occurrence data forms an important baseline for spatial and temporal comparisons and work that builds on such data (cf. also research projects of K. Linse, A. Brandt, D. Piepenburg, A. Purser, C. Richter). Species identity in itself can be difficult to establish. We routinely use standard molecular techniques (“barcoding”), which facilitate in many cases identification to species level (Grant et al. 2010). A single species, however, is not necessarily a homogenous, invariable unit, but mostly comprised of different individuals and populations with differing genetic background and spatial connections (Volckaert et al. 2012). Here, we employ state of the art genomic methods to characterize the population genetic status and connectivity of Antarctic fauna. In addition, we apply stable isotope analyses to determine trophic niche width, plasticity and overlap of the same taxa (as in e.g. Michel et al. 2016). These analyses are embedded in two Belgian research projects, that focus particularly on Antarctic target species across the animal kingdom: birds (*Pagodroma* spp.), fish (Notothenioidei), starfish (Asteroidea), feather stars (Crinoidea), and crustaceans (Amphipoda and Ostracoda).

Work at sea

Three types of gear will be used to collect benthic animals in the working area: the Agassiz trawl (AGT), the Rauschert dredge (RD), and an amphipod trap. Gears will be deployed in a similar fashion to previous expeditions (e.g. PS81, PS82, PS96), such that data should be comparable across expeditions. We aim at sampling a variety of stations in or adjacent to the sites of the (former) ice shelves Larsen A, B, and C. Spatial coverage, or in other words, sampling stations not too close together would be particularly interesting to provide sufficient contrast for later analyses. Ideally, all three gears are used at the same station (and also at stations where other biological sampling gear such as OFOBS, EBS, and ROV are deployed). Deployment of the amphipod trap will be opportunistic as it can only be used in good weather and ice conditions, and not deeper than 500 m.

When the catch is landed on deck, it will be photographed, weighed and if necessary sub-sampled. After sieving, specimens will be sorted to species/genus/class level (depending on taxa and available taxonomic expertise on board) and counted. These basic biodiversity data shall be shared with the other biology groups, facilitating the creation of a comprehensive biodiversity dataset for the entire expedition, that all users can build upon for further in-depth studies.

Selected target taxa from the catch will subsequently be further processed. Biopsies for genetic (barcoding and high-throughput sequencing) and stable isotope composition analyses will be taken and immediately fixed in pre-chilled RNAlater, 99 % molecular grade ethanol or frozen entirely. For these specimens also detailed ancillary data (pictures, length, weight, sex, maturity, or other, depending on the organism) will be collected. High quality metadata is indispensable for solid statistical analyses aiming at evaluating potential drivers of genetic or trophic diversity. For that we also depend on the oceanographic work conducted during previous and ongoing *Polarstern* expeditions. Subsequent laboratory procedures and eventually statistical analyses steps will be conducted at the respective institutions in Belgium.

Bird sampling (non-lethal, i.e. single feather samples) will only occur occasionally in case birds will land on the ship.

Expected results

Depending on ice conditions we expect to gather the first biological samples from newly exposed sea floor following the recent giant iceberg calving of the Larsen C ice shelf and adjacent areas. Such samples will be highly valuable to facilitate genomic and trophic studies that incorporate previously taken samples from other areas, such as from the Western Antarctic Peninsula and eastern Weddell Sea. They will thus contribute to the major research questions we have about genetic population structure, connectivity, adaptive potential, trophic plasticity, and niche partitioning.

Data management

Genetic data will be deposited in appropriate online databases (BOLD – The Barcode of Life Data System; SRA – The Sequence Read Archive of NCBI). When applicable, other data types will be deposited in suitable existing SCAR databases and linked to in the PANGAEA system.

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5. TRANSFORMATION OF ANTARCTIC BENTHIC FOOD WEBS ON THE LARSEN ICE SHELF FOLLOWING LOSS OF SEA-ICE-COVER (TABOSI)

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Objectives

Climate change has initiated major upheavals for polar biodiversity and ecosystems, such as for example the disintegration of the Larsen A, B and now C ice shelves. These newly ice-free areas provide a unique opportunity for ecosystem research of great relevance both for and beyond the Antarctic: Deep-sea organisms depend on organic matter produced in the upper ocean for food, and changes in upper-ocean conditions will therefore rapidly cascade to deep-sea ecosystems. But due to financial and logistical constraints we know very little about how benthic ecosystems at depth might respond to climate-driven changes in food supply. This project aims to document 'life' the transformation of former under-ice benthic communities on the Larsen C shelf following exposure to open water conditions. We will specifically study structure and efficiency of the benthic food web, and how it will change in response to the changes in primary production and, thus, food supply. Food web structure is a key ecosystem characteristic, and together with our German partners from AWI (community structure) and University of Rostock (benthic fluxes) we hope to gain a holistic picture of the short-term changes in the benthic ecosystem during PS118.

Food web structure is a key ecosystem characteristic, and profound knowledge of energy flow and organic matter cycling through and ecological interactions within an ecosystem is an essential prerequisite for the prediction of ecosystem-level response to perturbation and change. Isotope tracing experiments (ITEs) have in recent years provided a major step forward in attempts to describe the structure and functioning of deep-sea food webs (e.g. Witte et al. 2003, Gontikaki et al. 2011a). For organisms large enough to be identified and analysed individually (macro-,mega- and some meiofauna) they allow to directly link diversity to function on species or genus level and have great potential to enhance food web models (e.g. Gontikaki et al. 2011b). They have also proven particularly successful in assessing the impact of food supply and quality, or oxygen availability, on rates and pathways of deep-sea carbon cycling (e.g. Witte et al. 2003, Mayor et al. 2012, Hunter et al. 2012, Makela et al. 2018).

Specifically, we aim to investigate whether and how changes in food supply, and subsequent changes in benthic community composition (see ecological work programme in main cruise proposal S-2014-H-068; Dorschel et al.), will affect the rates and pathways of C and N cycling through the benthic community, addressing the following main objectives:

1. Quantification of rates and pathways of C and N cycling through the benthic community inside and outside the area formerly covered by A-68 by means of isotope tracing experiments (ITEs)
2. Determination of the trophic structure of the benthic food web inside and outside the area formerly covered by A-68 through bulk stable isotope analysis
3. Reconstruction of the benthic food web at our study sites through formulation of a linear inverse model based on data generated in 1. and 2., to further elucidate differences in food web flows between areas inside and outside the area formerly covered by A-68.

Work at sea

To achieve the above objectives, we propose to investigate shelf areas in front of the former Larsen C ice shelf (1st order priority area) and the bays of the former Larsen A and B ice shelves (2nd order priority area).

All food web investigations and tracer experiments will be carried out in close collaboration with the PS118 ecology team from AWI and the University of Rostock (U of Rostock). To maximise synergies, we will only select stations for food web studies and isotope tracing experiments where photographic information and benthic flux data are gathered by the AWI/ U of Rostock team. Exact transect and station positions will be determined in collaboration with the AWI colleagues based on the actual position of iceberg A-68.

We plan up to four stations outside the pre-calving Larsen C region and up to four stations inside this area, under the former ice shelf (former position of A-68). First priority will be stations outside the pre-calving and those inside the pre-calving shelf-ice edge but nearest to and furthest away from the pre-calving front, second priority will be the mid-distance stations.

Sediment cores will be taken and sieved on 250-µm sieves (0-10 cm) and macrofauna will be sorted to the lowest taxonomic level possible and processed for determination of C and N stable isotope rations as described in Mäkelä et al. (2017). A lipid correction will be performed where applicable, and $\delta^{15}N$ values will be obtained from non-acidified samples to avoid acidification impacts on $\delta^{15}N$ values.

Differences in the rates and pathways of C cycling by the benthic community inside and outside the pre-calving shelf-ice edge will be tested in ITEs with freeze-dried $^{13}C/^{15}N$-labelled algal biomass at up to 6 stations as described for example in Mäkelä et al. (2017). The sediment community oxygen consumption (SCOC), the amount of $DI^{13}C$ released into the overlying chamber water, $DI^{13}C$ porewater profiles and the amount of tracer ^{13}C and ^{15}N taken up by the different benthic organisms will be compared. We expect respiration and turnover ($DI^{13}C$) rates to be higher and label entrainment into the sediment to be faster and deeper at stations with longer exposition to open water conditions.

Eexpected results

Results will help understand and predict to what extent the loss of shelf ice and subsequent exposure to open water conditions will change benthic food webs and the efficiency with which they recycle organic matter reaching the seafloor – on the deep Antarctic shelf, and in the deep-sea in general.

Data management

Most data will be obtained through laboratory analyses after the cruise. Processed data will be uploaded to the databases PANGAEA and/or UK-PDC.

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6. LARSEN BENTHO-PELAGIC PROCESSES

C. Richter (AWI), M. Baloza (AWI), M. Holtappels (AWI), N. Owsianoski (AWI), H. Schröder (AWI)

Objectives

Our research objectives are the quantitative description of the structure and function of the Antarctic shelf benthos, its interaction with the pelagial, its carbon turnover and its susceptibility to natural and climate-induced disturbances as a basis for the modelling of biological response to climate change. It is postulated that the environmental changes associated with climate change (ice shelf decline, sea ice and polynya development, upwelling of modified deep water onto the Antarctic shelf) affect the structure and function of Antarctic benthos. However, the mechanisms underlying the biological changes observed so far are only poorly constrained. The journey PS118 should help to better understand the dynamics of the Antarctic benthos and its ecological functions.

Our focus is on the Larsen A, B and C areas, covered until recently with ice shelves. Larsen A and B collapsed in 1995 and 2002, and were first investigated in 2007 (PS69, Gutt et al. 2011) and four years later (PS77, Fillinger et al. 2013; Gutt et al. 2013). Significant changes in the species composition, abundance and biomass of the dominant species were identified, which challenge the paradigm of an extremely slow-growing megabenthos (Fillinger et al. 2013; Barnes 2013). The diversity and abundance of benthos below the millennia-old ice shelves is still unknown, since earlier expeditions could never determine whether the species found were originally present or whether they had immigrated (Gutt et al. 2011). Here, the recent calving event of the massive iceberg A-68A from the Larsen C area in 2017 offers a unique opportunity to determine the structure and function of the benthos very near to its "original state" until 2017.

A repetition of remotely operated vehicle (ROV) transects from earlier expeditions to Larsen A and B should provide information on the further development of benthos and test whether the Antarctic shelf is a carbon sink (Peck et al. 2010). Using a 3D modelling method developed in-house (Fillinger & Funke 2013), archived video surveys can be compared with new video material from the same area and temporal changes in species and size spectra can be detected. Important conclusions on population changes in connection with natural disturbances (icebergs) and climate change (pack ice, shelf ice, hydrographic changes) can be derived from this.

Benthic oxygen flux measurements are important to characterize the various habitats and estimate their rate of organic matter remineralization (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 pack-ice covered western areas (Voß 1988). It is likely that in the Larsen C area, benthic fauna biomass and productivity is very low. 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 complement current P/B estimates with direct community respiration measurements.

Besides profound effects on benthic habitats, the Antarctic ice shelves themselves offer a unique habitat. An exploratory 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. As we found the under-ice species *Antarcturus cf. spinacoronatus* also in high densities on the seafloor during the PS77 benthic surveys, an additional objective is to search for this species both on the seafloor and on the ice-shelf in the Larsen area.

The objectives of this study are thus four-fold: (i) to explore the benthic fauna in the Larsen C region, a region of continuous ice-shelf cover for millennia, (ii) to repeat the surveys in the Larsen A, B and control areas to assess the dynamics of Antarctic benthic community succession years and decades after ice-shelf collapse, (iii) to measure benthic oxygen uptake rates relating benthic biomass to benthic respiration and organic matter supply, and (iv) 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).

Work at sea

Within the context of the benthic working programme of the PS118 cruise, seabed imaging will be carried out with a ROV in the Larsen A, B and C areas 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 epi-megafauna in its environmental context. Repeat transects of ROV tracks carried out on earlier cruises will allow to monitor changes in epi-benthic groups over time and assess the community dynamics over decadal time scales. During the same transects, the ROV will be used also for targeted sampling to obtain minimally invasive in situ water samples as well as individual sponges and corals for experiments and molecular investigations. Within the context of the ice-shelf work, the ROV will provide imaging of the ice-shelf from the surface to its underside. A brush-sampler, successfully deployed during PS96, will allow us to collect isopod samples for subsequent analyses of population genetics, diet and on-board incubations.

To assess benthic oxygen fluxes *in-situ* in combination with the physicochemical conditions of the water column, a moored lander system will be deployed for 24-48 h at each benthic station. A lander-mounted upward-looking ADCP will measure current profiles, and CTDs spaced along the mooring line with auxiliary O_2, pH, chl a fluorescence, PAR sensors will measure the water column properties aloft the lander. The lander itself will be equipped with (i) two Eddy Covariance systems measuring the oxygen flux across the benthic boundary layer (Holtappels et al. 2013), and (ii) a microsensor profiling system carrying out autonomous O_2 profiles through the upper sediment layers to quantify the diffusive oxygen utilization of the sediment. Flow in the boundary layer will be measured by ADCP and ADV.

A Multicorer (MUC) will be deployed in cooperation with the biological and geological teams in Larsen and control sites. Sediment porewater will be analyzed by measuring profiles of oxygen and nutrient concentrations, and cores will be incubated for benthic oxygen uptake measurements as a function of macrobenthic biomass and organic carbon content.

Expected results

Pending ice conditions, we expect important new insights into a natural benthic recolonization experiment successively triggered by the 1995, 2002 and 2017 ice shelf changes on the western Weddell Sea continental shelf. We expect to underpin our findings on temporal changes in benthic abundance and biomass with *in-situ* measurements of 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 relation to the environmental conditions governing these upside-down filter-feeding communities.

Data management

Data will be made available in PANGAEA.

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7. MARINE GEOLOGY AND SEDIMENT PHYSICS

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Objectives

Observations made over the past years indicate climatic changes along the Weddell Sea side of the Antarctic Peninsula (AP). In this context of particular importance is the almost complete collapse of the ice shelves Larsen A (in 1995) and Larsen B (in 2002). In addition, a large area broke off the Larsen C ice shelf in 2017, creating a giant iceberg of 175 km in length. This calving event may be a precursor and likely reminds us of the vulnerability of the last remaining ice shelf in the west Weddell Sea in times of rapid global change. As a consequence and large scientific challenge, previously inaccessible sub-ice shelf-seabed regions became available for field work to address geo-scientific research issues such as the history of the West Antarctic Ice Shield linked to ice-shelf dynamics, sea-ice conditions and their control on the formation of the Weddell Sea Antarctic Bottom Water (WSABW). Thus, the geo-specific goals of Leg PS118 are three-fold:

- Reconstructing the late Pleistocene dynamics and drainage patterns of the Larsen ice sheets, ice shelves and sea-ice dynamics across the western Weddell Sea shelf and continental margin using hydroacoustic sea-floor and sediment-core data.
- Search for palaeo subglacial lake or sub-ice-shelf cavern sediments in sedimentary basins in front of the ice shelves.
- Quantification of the relative contributions of various regional Weddell Sea Deep Water masses that form Weddell Sea Antarctic Bottom Water in space and time using Nd and Hf isotope compositions of water and sediment samples.
- Extension of Antarctic surface sediment data sets for geochemical proxy calibrations.

In the years following the Larsen B collapse, expeditions with *Polarstern*, *James Clark Ross* and *Palmer* mapped parts of this newly exposed sub-ice shelf seabed and discovered paleo-sub-ice-bedforms such as drumlins, eskers and mega scale glacial lineations (MSGL). From these bedforms, information on ice stream flow directions and sub-ice hydrological and glaciological processes can be derived (Davies et al. 2012; Evans et al. 2005; Rebesco et al. 2014) thus providing key information for the reconstruction of glacial and environmental developments on the eastern margin of the AP (Domack and Ishman 1993; Domack et al. 2005; Evans et al. 2005; Gilbert and Domack 2003; Gutt et al. 2011; Pudsey and Evans 2001;

Pudsey et al. 2006; Rebesco et al. 2014). This enhances the understanding of the spatial and temporal deglaciation history of the AP glaciers and Ice Sheet (O'Cofaigh et al. 2014), and the implications on sedimentary and biological processes on shelves and continental slope of the west Weddell Sea. However, in order to understand the Larsen ice shelf dynamics, it is critical to combine information on the seabed morphology with paleoceanographic interpretations based on sediment cores. It is also critical to reconstruct and discriminate between past coverage by sea ice (Belt et al. 2016) and shelf ice by means of biomarker analyzes of sediments. For the temporal context, it is essential to determine the ages of the sediments covering the glacial bedforms. Dating of the shelf sediments is, however, difficult, due to the sparse distribution of dateable carbonate material and unknown 14C reservoir ages, but newer technologies need less amount of carbon for dating (Klages et al. 2014). One major target of leg PS118 is the discovery of depressions on the western Weddell Sea shelf which act as natural sediment traps to provide high resolution Holocene sediment records of the natural dynamics of shelf and sea ice distributions along the AP since the Last Glacial Maximum. Moreover, shelf depressions can preserve lacustrine sediments deposited in subglacial lakes at times when the AP ice sheet covered the entire shelves (Kuhn et al. 2017). An additional site of scientific interest of leg PS118 is located on the continental slope of the AP off the Larsen A and B ice shelf. During previous expeditions a giant Plio/Pleistocene slide has been discovered extending for almost 100 km in north-south direction across the Larsen continental slope (Jokat and Krause 2003). According to stratigraphic correlation between existing ODP drill holes in the Weddell Sea, age estimations for the Larsen slide range between 0.5 to 8 Myr. A likely period for the slide to occur was the Plio/Pleistocene transition at around 3Myr, when the Antarctic glaciation intensified and mass wasting is reported also from other parts of Antarctica. The question addressed in the scope of this work is, whether or not repeated disintegrations of the Larsen Ice Shelf in the past were the reasons for this submarine mass waste.

Besides the glacial morphological focus presented above for our PS118 participation, we also want to better characterise individual water masses for their radiogenic isotopic composition, and apply this newly gained information to reconstruct Weddell Sea water mass mixing processes in the past thousands of years. The Weddell Sea is the formation area of the most important variety of Antarctic Bottom Water (AABW) today (Orsi et al. 1999). While this globally important water mass and its generation has been relatively well studied using physical oceanographic tools (Schröder et al. 2002; van Caspel et al. 2015), to date virtually no information exist on the neodymium (Nd) or hafnium (Hf) isotopic composition of the respective precursor water masses within the Weddell Sea. Seawater Nd and Hf isotopic compositions are largely controlled by the supply of continental subglacial runoff, which in turn are controlled by the average continental isotopic composition in near-coastal hinterland of Antarctica. In the absence of regional or local continental input, water masses carry an advected signature transported over longer distances that can equally be resolved, providing information towards the flow path and water mass mixing proportions. CTD-based seawater sampling was carried out during PS111 in 2018 for the characterisation of the dissolved Nd and Hf isotopic composition in the southwestern Weddell Sea in order to quantify the relative contributions of various regional Weddell Sea Deep Water masses that ultimately form WSABW. The previous sampling campaign was very successful, including the sampling of the entire Ronne-Filchner Trough shelf ice edge, as well as a variety of stations further north in the open southern Weddell Sea. CTD Seawater sampling to be carried out during PS118 will complement the previous sample set. During PS118 we aim to characterise the northwestern part of the Weddell Sea, including the suggested Larsen Ice Shelf region AABW formation area (van Caspel et al. 2015). Once the characterisation of the southern and northwestern AABW precursor water masses in the modern water column is completed, we aim to reconstruct the evolution of Weddell Sea Deep Water export back into the last glacial cycle. This objective will be realised by targeting marine sediments to be recovered during PS118. Marine sediments contain an authigenic Fe-Mn oxyhydroxide fraction that stores the bottom water Nd and Hf isotope signatures of the water masses prevailing at the time of sediment deposition. We can extract this bottom water signature with a gentle reductive solution (Gutjahr et al. 2007; Blaser et al. 2016).

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. If applicable, the giant box corer will be used as well. Longer sediment cores will be obtained using the gravity corer at sites surveyed by the hull-mounted sub-bottom profiler PARASOUND in operation along the entire track of the cruise. Correlation of cores with hydroacoustic records will allow to extrapolate spot information from samples into space and time of the sedimentary environment. Gravity cores will be cut into 1-m-sections and stored at 4°C. Prior to storage all core sections will be analyzed for whole-core physical properties using a Multi- Sensor-Core-Logger (MSCL-S, Geotek Ltd.). The MSCL device provides data in 1-cm-depth intervals of wet-bulk density, porosity, p-wave velocity and magnetic susceptibility. Full processing of MSCL raw data will be carried out at sea so that high resolution records of physical properties will be available during the cruise. However, gravity cores remain un-split until the home laboratory as a result of limited capacities of the small group of geo participants during the cruise. Sampling of the MUCs (1 cm slices) into combusted glass vials (biomarker) and Whirlpack sampling bags (sedimentology, micropaleontology) will take place onboard. Samples designated for biomarker studies at home laboratories at AWI need to be stored frozen (-20°C). Water samples will be filtered on board, acidified and subsequently co-precipitated. The geological sampling sites will be decided based on the bathymetric and sub-bottom information. Proposed sampling targets are thin drape and drift deposits that can be fully penetrated down to the underlying till successions. Special emphasis will be on grounding lines, moraines and scour marks. Additional targets are sites of potential high-resolution Holocene climate records. Selected bedforms will be target-sampled using gravity, box and multi-corer equipped with a Posidonia beacon for exact positioning when needed. For the reconstruction of Weddell Sea AABW export we place a high priority on obtaining a sediment-core transect along the northwestern export pathway of AABW in various water depths (*cf*. Schröder et al. 2002). This will always be a combination of MUC and gravity cores, making sure to sample an undisturbed seafloor including the MUC water enclosed during sampling, as well as sediments within reach of the gravity core.

Expected results

In particular for the shelf areas in front of the Larsen C ice shelf (1st order priority area) and the bays of the former Larsen A and B ice shelves (2nd order priority area), we expect an initial and further characterization, respectively, of the sea floor and sediments with respect to former ice coverage, sub-ice hydrological conditions (sub-glacial lakes, meltwater channels), ice-flow dynamics and possible past natural collapse(s) of ice shelves. The multi-proxy approach of combining hydroacoustic data of glacial bedforms on the shelves and margins, sedimentological interpretation of dated cores and biomarker information on past sea ice coverage will gain new fundamental results on the dynamic behaviour of the cryosphere along the AP during the Pleistocene and Holocene. Core records of physical properties will provide a preliminary stratigraphical framework for the areas under investigation and provide a first lateral correlation and extrapolation into the sedimentary environment.

Together with sediment-based results already generated within the PhD work of Huang Huang at GEOMAR Kiel, we will be able to identify if and under which climatic boundary parameters the export of AABW may have been reduced, or possibly even halted. Since we will have a very good understanding of the Nd isotopic composition of the Larsen, Filchner, and Ronne shelf area water masses – precursors to Weddell Sea AABW –we aim to make estimates for relative contributions of the various water masses in Weddell Sea AABW back through the Holocene and beyond.

Data management

At the end of the cruise all PARASOUND data (PHF and SLF) will be stored in ASD, PS3, and SEG-Y formats on the *Polarstern* data mass storage and from there transferred to the AWI computer center to be safely stored and linked to PANGAEA after geo referencing. Finally, all data of the geo group will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, depending on analysis in the home laboratories and publication.

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8. GEOTHERMAL GRADIENTS AND HEAT FLOW ESTIMATES

R. Dziadek (AWI), N. Kaul (University of Bremen, not on board)

Objectives

(Marine) geothermal heat flow (GHF) observations provide fundamental constraints on physical, chemical and biological processes occurring near and below the seafloor. Processes that influence and are influenced by heat transport within seafloor sediments and basement rocks include: (1) the thermal evolution of the oceanic crust and lithosphere; (2) the geodynamics of plate boundaries and mantle convection; (3) fluid circulation and associated impacts on water-rock/ice-rock interactions, seismicity, tectonics, and magmatism. Understanding these processes involves the quantification of energy and fluid fluxes, requiring knowledge of the thermal state deduced from observations that include heat flow, sub-bottom temperature, and thermos-physical sediment properties.

The thermal state of Antarctic crust plays a crucial role for understanding the stability and height of large ice sheets, the visco-elastic response of the solid-Earth due to unloading, when large ice caps melt and, in turn, the accuracy of future sea level rise prediction. The scientific community repeatedly outlined the importance of better constrained boundary conditions to enhance the accuracy ice sheet model performance for future sea level rise predictions.

Continent-wide GHF is estimated by indirect methods, such as magnetic and seismological data, and show large inconsistency between models (Fox Maule, Purucker, Olsen, & Mosegaard 2005; Martos et al. 2017; Purucker 2012), which leads to ambiguous results when applied to ice sheet flow models. Regional GHF estimates are based on crustal heat production in the onshore area of the Antarctic Peninsula and indicate spatial variabilities (Burton-Johnson, Halpin, Whittaker, Graham & Watson 2017). Furthermore, locally elevated GHF due to volcanic activity e.g. in the vicinity of James Ross island, could contribute to a latent instability of the West Antarctic Ice Sheet in this region (Nicholls & Paren 1993; Zagorodnov et al. 2012).

The objective of our temperature measurements during *Polarstern* Cruise PS118 is an assessment of the *in-situ* geothermal heat flow in the Weddell Sea region, which will provide crucial ground-truthing for the currently existing GHF models.

Work at sea

We plan to deploy miniaturized temperature logger with 0.001 K resolution, 0.1 K precision and sampling intervals of 1 to 2 s (Pfender & Villinger 2002). They will be equidistantly mounted on either A) an up to 7-meter-long thermal probe or B) the gravity corer to monitor the water column temperature profile and *in-situ* sediment temperature gradients. Prior to deployment, the MTL will be calibrated for absolute temperatures with the ships SBE911plus CTD (conductivity, temperature, and depth) in the water column. After calibration the offset between MTL and CTD will be estimated. The accuracy of a MTL measurement (0.1 K) depends on static errors (calibration and stability) as well as dynamic errors in the environment. Additional weights will be mounted on the upper part of the thermal probe to support the penetration into the sediment. An additional MTL will be mounted above the probes weight to measure the water temperature at the sea floor during penetration. The deployment phases consist of several stages. In the first stage the probe is lowered through the water column, when entering the sediment the temperatures typically rise at first due to the frictional heat. Furthermore, the frictional heat is an indicator, that the sensor has entered the sediment. This can in some cases also be confirmed by a brief visual inspection of sediment coverage of the probe once it was hoisted back on deck. We will use an up to 10-minute steady-time, where the probe rests in the sediment, which allows for the frictional heat to decay and the temperatures to adjust to ambient sediment temperatures. During stage 3 the sediment temperatures stabilize. The mean temperature of the stabilization phase will be plotted against the depth of the sensors to obtain the geothermal gradient. The thermal conductivity (k) will be measured on gravity cores on board at stable ambient temperatures, taken in the vicinity of or at the GHF sites with a KD2 Pro Thermal Property Analyzer that has an accuracy of ±5% from 0.2 to 2 Wm-1K-1 (Decagon Devices Inc., 2012). The 6 cm long sensor applies a very small amount of heat to the needle which helps to prevent free convection in liquid samples. Because of the sensors heat pulse, a minimum of 1.5 cm of material parallel to the sensor in all directions needs to be allowed to minimize errors. The sampling frequency along the cores will range between 10 cm to 50 cm. The heat flow will then be calculated from the product of thermal conductivity and temperature gradient.

Expected results

We expect a suite of *in-situ* temperature measurements in the eastern Weddell Sea region, which will yield crucial implications for spatial variabilities of GHF and ground-truthing for existing GIA and Ice Sheet models. These can be linked to geodynamic processes in the Antarctic Peninsula for understanding the isostatic response caused by ice unloading, better constraints of boundary conditions for ice sheet models and related sea level rise predictions.

Data management

The data sets measured and computed for this study will be available at PANGAEA database (https://www.pangaea.de) after publication or from the authors upon request (ricarda.dziadek@awi.de).

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9. HYDROACOUSTICS

S. Dreutter (AWI), N-M. Lešić (AWI), M. Lütjens (AWI), F. Warnke (AWI), B. Dorschel (AWI)

Objectives

Accurate knowledge of the seafloor topography, hence high-resolution bathymetry data, is key basic information necessary to understand many marine processes. It is of particular importance for the interpretation of scientific data in a spatial context. Bathymetry, hence geomorphology, is furthermore a basic parameter for the understanding of the general geological setting of an area and geological processes such as erosion, sediment transport and deposition. Even information on tectonic processes can be inferred from bathymetry. Supplementing the bathymetric data, high-resolution sub-bottom profiler data of the top 10s of meters below the seabed provide information on the sediments at the seafloor and on the lateral extension of sediment successions. In this way, the sub-bottom data supplements the 3rd dimension to the bathymetric maps.

Beside very few bathymetric survey lines, the Larsen C continental shelf is entirely unmapped by high-resolution swath bathymetry systems. For these areas, the bathymetry is modelled from satellite altimetry with according low resolution. Satellite altimetry derived bathymetry lack the resolution necessary to resolve small- to meso-scale geo-morphological features (e.g. iceberg ploughmarks, sediment waves, and erosional escarpments). Ship-borne multibeam data provide bathymetry information in a resolution sufficient to resolve those features. Hydroacoustic data furthermore provide valuable information for site selection for the other scientific working groups on board.

Work at sea

Bathymetric data will be recorded with the hull-mounted multibeam echosounder Atlas Hydrosweep DS3, and sub-bottom data will be recorded with the hull-mounted sediment echosounder Atlas Parasound P70. The main task of the bathymetry group is to plan and run bathymetric surveys in the survey areas and during transit. The raw bathymetric data will be corrected for sound velocity changes in the water column and will be further processed and cleaned for erroneous soundings and artefacts. Detailed seabed maps derived from the data will provide information on the general and local topographic setting in the study areas. High-resolution seabed and sub-bottom data recorded during the survey will be made available for site selection and cruise planning. During the survey, the acoustic measurement will be carried out by three operators in a 24/7 shift mode (except for periods of stationary work).

Expected results

Expected results will consist of high-resolution seabed maps and sub-bottom information along the cruise track and from the target research sites. The bathymetric and sediment acoustic data will be analyzed to provide geomorphological information of the research area. Expected outcomes aim towards a better understanding of the geological and, particularly, the sedimentary processes in the research area.

Data management

Bathymetric data collected during the expedition will be stored in the PANGAEA data repository at the AWI. Furthermore, the data will be provided to mapping projects and included in regional data compilations such as IBCSO (International Bathymetric Chart of the Southern Ocean) and GEBCO (General Bathymetric Chart of the Ocean). Bathymetric data will also be provided to the Nippon Foundation – GEBCO Seabed 2030 Project.

References

none

10. OCEANOGRAPHIC CONDITIONS IN THE LARSEN C ICE SHELF REGION IN THE WESTERN WEDDELL SEA

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Objectives

The disintegration of ice shelves Larsen A in 1995 and Larsen B in 2002 left Larsen C as the last remaining ice shelf in the western Weddell Sea. However, the recent calving of a massive portion of Larsen C in 2016 suggests that further changes are to be expected there as well with likely impacts on the dynamics of adjacent glacier systems and the West Antarctic ice sheet in general. Some Antarctic regions feature dramatic sub-ice shelf melt rates due to the interaction of warm water masses with the ice shelves. Ice shelf-ocean interaction at Larsen and the regional oceanography is poorly understood due to the difficult access, explained by the cyclonic Weddell Gyre circulation causing the accumulation of often thick ice on the western Weddell Sea shelf. The main objectives of the oceanography activities during PS118 include therefore to improve the general understanding on ocean circulation, water masses and physical mechanisms, to assess the ocean's role in the decay of the ice sheets, and to understand whether retreating ice shelves may change water mass formation and ocean circulation.

Water masses that are formed along the ice shelf margins of the Weddell Sea are regionally important and contribute to the global ocean circulation. High salinity shelf water (HSSW) is formed in polynyas on the continental shelves and is characterized by saline waters near the surface freezing point. When HSSW sinks to greater depths, its temperature is above the local freezing point and upon entering the cavities below the ice shelves, HSSW can cause melt at the underside of the ice shelf. During this stage, HSSW cools and freshens due to ice melt and exits the cavity as a supercooled (<-1.9°C) water mass termed Ice shelf water (ISW). These shelf-formed water masses (ISW and HSSW) along with the warmer waters that originate from the deeper Weddell Sea (modified Weddell Sea deep water; MWDW) characterize the regions' water masses, and PS118 aims at understanding their distribution and further pathways. The prevailing sea ice circulation allows easier access to the southern Weddell Sea, which is why the circulation patterns and water masses off the Filchner and Ronne ice shelves are comparatively better understood than the Larsen region. However, the PS118 expedition will provide the unique opportunity to shed new light on one of the most rapidly changing regions in the western Weddell Sea.

This expedition is closely connected to the ongoing activities in the southern Weddell Sea, as it connects the sea ice and water mass source regions in Filchner and Ronne with the throughflow area of the Larsen continental shelf. Sampling strategies and data analysis will benefit from the knowledge gained during previous *Polarstern* expedition (PS96, PS111) and from the monitoring of hydrographic properties underneath the Filchner Ice Shelf. The fieldwork will be based on traditional oceanographic sampling methods (CTD, ADCP) complemented by more specialized methods (microstructure measurements, sea gliders, autonomous drift systems), designed to achieve a regional-scale hydrographic overview guided by the bathymetric surveys, as well as to understand the smaller-scale processes that are important for water mass transformation, vertical fluxes, and bio-physical ecosystem processes.

Specific objectives

- Specify the physical properties controlling the flow and water mass formation on the western Weddell Sea shelf and slope using CTD and glider surveys
- Determine the temporal variability of the hydrography and tracer distribution on the continental shelf and slope with regard to Ice Shelf Water outflow, Antarctic Bottom Water formation, Modified Warm Deep Water inflow, and High Salinity Shelf Water spreading.
- Provide a comprehensive dataset for numerical model validation and initialisation
- Re-visit some previously occupied hydrographic stations on the western Weddell Sea continental shelf and slope for a new snapshot of the dominant water masses
- Provide an improved estimate of glacial melt water inventories and basal melt rates for the western Weddell Sea (Larsen Ice Shelf) to deduce temporal trends in the future
- Determine vertical fluxes of heat and nutrients in the western Weddell Sea
- Understand the role of canyons in guiding dense water masses off the shelf
- Utilize tracers (stable noble gas isotopes [^{3}He, ^{4}He, Ne]) to quantify subglacial meltwater drainage and ice shelf basal melting
- Utilize tracers to quantify Antarctic Bottom Water formation (transient trace gases [CFCs] to identify transit time scales and formation rates)

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. A minimum of 150 ship-based CTD-casts, and another 30 helicopter-based CTD or MSS 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) crossing the continental slope and shelf, and (3) along and across the down-slope path of northward flowing ISW/WSBW. Standard CTD stations will be complemented by ship- or helicopter/ice-based microstructure profiling stations, in order to determine mixing rates and vertical fluxes of heat, salt and nutrients. Additionally, two seagliders will increase the spatial resolution of measurements by autonomously sampling hydrographic and bio-optical parameters along pre-defined transects across the study region. The gliders will be operated by cruise participants from the University of East Anglia, UK. Short-term moorings in collaboration with the benthic flux group will sample physical and biological parameters at high frequency in order to understand the role of tides or internal waves for water mass transformation and fluxes of heat and matter. For longer-term perspectives we plan to deploy two drifter systems on the sea ice. The systems are equipped with CTDs and current meters and will transmit data via satellite for an expected period of 1-2 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.

Expected results

The oceanographic results obtained during PS118 should shed new light on the hydrography of the sparsely sampled western Weddell Sea. In particular, sea glider and ice-based microstructure measurements in combination with the benthic lander moorings should result in new findings regarding smaller-scale physical processes. Finally, the cooperation between different groups on PS118 bears the potential for numerous interdisciplinary findings, including the identification of flow pathways from the shelf to the deep ocean in collaboration with the bathymetry group, as well as to promote the bio-physical understanding in collaboration with biologists and sea ice scientists.

Data management

Soon after the end of the expedition, a final calibration of the hydrographic data will be done using standard procedures. The preparation of the 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.

11. OBSERVATION OF OCEANIC TRACE GASES: STABLE NOBLE GAS ISOTOPES (^{3}HE, ^{4}HE, NE) AND TRANSIENT ANTHROPOGENIC TRACERS (CHLOROFLUOROCARBONS, CFCS)

A. Röhler (UHB-IUP), O. Huhn (UHB-IUP, not on board), M. Rhein (UHB-IUP, not on board)

Objectives

Model studies and rare oceanic observations emphasize the complex and unique interaction of the Antarctic Ocean climate components (atmosphere – sea ice – shelf ice – ocean) and their sensitivity to changing environmental conditions and response to climate change. The Weddell Sea Deep and Bottom Water (WSDW, WSBW) formation and composition is known to be strongly related to the dynamics of the ice shelf in the southern Weddell Sea (Filchner Ice Shelf) and very likely the western Weddell Sea (Larsen Ice Shelf, LIS, van Caspel et al. 2015; Huhn et al. 2008). Recent observations show distinct variability or even trends in the WSBW properties (warming, freshening, water mass age increase, reduced ventilation and reduced anthropogenic carbon uptake, (Fahrbach et al. 2004; Huhn et al. 2013)). In 2017 a giant ice berg calved off Larsen C. However, the actual state of basal ice shelf melting at LIS, its variability and possible future trends due to changing climate conditions and its impact on the WSBW formation and composition and its variability is not yet fully understood.

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

Investigating and quantifying basal glacial melting and the related WSDW/WSBW formation as close as possible to its sources (LIS) 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 [CFC-12 and SF6] to determine transit time scales and formation rates) and their variability.

The aims of the project are:

- To produce an actual estimate of glacial melt water inventories and basal melt rates for the LIS in the western Weddell Sea
- To trace the pathways of the glacial melt water, how it contributes to local WSDW/WSBW formation, and to quantify the related actual WSDW/WSBW formation rates.
- To investigate the possible variability or to find evidence for temporal trends in glacial melting processes and related WSDW/WSBW formation. Possible variability could be detected by comparison with observations from previous expedition, e.g. ANT-29/3, 2013, and ANT-22/2 (ISPOL), 2004/05.

Oceanic measurement of low-solubility and stable noble-gases helium (^{3}He, ^{4}He) and neon (Ne) provide a useful tool to identify and to quantify basal glacial melt water (Schlosser 1986; Schlosser et al. 1990). Atmospheric air with a constant composition of these noble gases is trapped in the ice matrix during formation of the meteoric ice. Due to the enhanced hydrostatic pressure at the base of the floating ice, these gases are completely dissolved, when the ice is melting from below. This leads to an excess of helium +1,260 %, and neon +890 % in pure glacial melt water compared to atmospheric equilibrium at the ocean surface (Loose & Jenkins, 2014). Frontal or surface melt water would equilibrate quickly with the atmosphere and not lead to any noble gas excess in the ocean water. With an accuracy of <0.5 % for He and Ne measurements performed at the IUP Bremen, basal glacial melt water fractions of <0.05% are detectable. Helium has an additional oceanic source (primordial helium from hydrothermal activity with a distinct higher ^{3}He/^{4}He isotope ratio), which neon does not have.

The transient trace gases chlorofluorocarbons (CFC-12 and SF6) are completely anthropogenic and enter the ocean by gas exchange with the atmosphere. Since the evolution of these transient tracers in the ocean interior is determined on first order by their temporal evolution in the atmosphere and subsequently by advection and dispersion in the ocean interior, they allow estimating the time scales of the renewal and ventilation of inner oceanic deep and bottom water masses. This is often referred to as an "age" of a water mass, i.e. the time elapsed since the water has left the surface.

The combination of the CFC and SF6 based "ages" and the noble gas based melt water inventories allow estimate basal glacial melt rates and the formation rate of deep and bottom water.

Work at sea

We intend to obtain about 200 water samples for noble gas isotopes and about 200 water samples for CFC and SF6 from the ship deployed full depth profiling CTD and water sample system.

The oceanic water samples for helium isotopes and neon will be stored from the CTD and water bottle system into 50 ml gas tight copper tubes, which will be clamped of at both sides. The noble gas samples are to be analyzed later in the IUP Bremen noble gas mass spectrometry lab. The copper tube water samples will be processed in a first step with an ultra-high vacuum gas extraction system. Sample gases are transferred via water vapor into a glass ampoule kept at liquid nitrogen temperature. For analysis of the noble gas isotopes the glass ampoules are connected to an ultra-high vacuum mass spectrometric system equipped with a two-stage cryogenic trap system. The system is regularly calibrated with atmospheric air standards (reproducibility better ±0.2 %). Also measurement of blanks and linearity are done. For details see Sültenfuß et al. 2009.

Water samples for CFC and SF6 measurements will be stored from the ship deployed water samplers into 200 ml glass ampoules and will be sealed off after a CFC and SF6 free headspace of pure nitrogen has been applied. The CFC samples will be later analyzed in the CFC and SF6 laboratory at the IUP Bremen. The determination of CFC and SF6 concentrations is accomplished by purge and trap sample pre-treatment followed by gas chromatographic (GC) separation on a capillary column and electron capture detection (ECD). The amount of CFC and SF6 degassing into the headspace is accounted for during the measurement procedure in the lab. The system is calibrated by analyzing several different volumes of a known standard gas. Additionally the blank of the system are analyzed regularly. For details see Bulsiewicz et al. 1998.

Expected results

The oceanic measurements of stable noble gas isotopes (^{3}He, ^{4}He, Ne) and transient trace gases (CFC-12 and SF6) will allow to identify and to quantify basal ice shelf meltwater and its inventories in the western Weddell Sea at LIS and to assess the related WSDW/WSBW composition, its formation rate, its transfer into the deeper Weddell Basin and its further export. It will increase our understanding of basal shelf ice melting and WSDW/WSBW formation quantitatively and how they evolve under changing climate conditions.

Data management

Due to shipping home, the extensive treatment of the samples in the IUP home labs, and an accurate quality control, the results of the measurements are expected for 2020. The data will be made available to our colleagues as soon as possible. Once published, we will store them in the PANGAEA data base.

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12. SEABED HABITAT MAPPING AND BENTHIC MACROECOLOGICAL STUDIES WITH THE OCEAN FLOOR OBSERVATION AND BATHYMETRY SYSTEM (OFOBS)

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Objectives

General

Recent studies indicate increasing climate change processes in the maritime Antarctic, with significant environmental impacts. Off the eastern coast of the Antarctic Peninsula, the almost complete disintegration of the ice shelves Larsen A in 1995 and Larsen B in 2002, as well as the break-off of giant icebergs from Larsen C (e.g. Shepherd et al. 2003, Wendel & Kumar 2017) have resulted in such spatially extensive habitat change.

By investigating the seafloor habitats and associated benthic fauna in these recently ice-free regions with the Ocean Floor Observation and Bathymetry System (OFOBS), the ecological effects of this climate-driven ice shelf loss can be studied with far greater ease than was possible previously. OFOBS is a towed device capable of deployment in moderately ice-covered regions and capable of concurrently collecting acoustic as well as video and still image data from the seafloor (Purser et al. 2018). These data will serve two purposes: (1) habitat mapping, and (2) macroecological studies of megabenthic biodiversity patterns. Moreover, obtained data will be directly comparable with image, video, and high-resolution sidescan data, collected from the Weddell sea during other recent *Polarstern* cruises, such as PS81 in 2013 (Gutt et al. 2013) and PS96 in 2015/16 (Cape et al. 2014).

Habitat mapping

OFOBS data streams will be integrated to produce high-resolution 3D spatial models (topographic maps) of the seafloor. These models will allow subsequent high-resolution analysis of terrain variables, such as slope, aspect and rugosity, and their relationship to the distribution of benthic fauna on a finer scale than has previously been possible in the Weddell Sea. This study will provide the first combined image / acoustic data set collected by towed sled deployment within the Weddell sea, and if the recently exposed seafloor regions of Larsen C are reachable, this will form an important record of the first stages of ecosystem change in the region after the recent shelf ice removal. Moreover, OFOBS-derived information will support the work of the other biologist / ecologist cruise participants and onshore collaborators.

Macroecological studies

OFOBS images will be surveyed for the composition, diversity and distribution of megabenthic assemblages, i.e., those seafloor organisms that are large enough to be visible in seabed images, providing results that are comparable with earlier studies (Gutt et al. 2016). Megabenthic fauna are of very high ecological significance for the Antarctic shelf ecosystems. They strongly affect the small-scale topography of seafloor habitats and do thus exert prime influence on the structure of the entire benthic community. Some species are especially sensitive to environmental change due to their slow growth, specific reproduction mode, high degree of environmental adaptation and narrow physiological tolerances. Therefore, they can serve as early indicators of ecosystem shifts after ice-shelf disintegration.

Work at sea

General

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

Habitat mapping

In addition to collecting image data comparable with those collected from the region and surrounding areas by preceding survey cruises, OFOBS will also collect in parallel high-resolution topographical information from the seafloor by using a sidescan sonar system and a forward-facing acoustic camera. The sidescan system allows a ~100 m swath of seafloor to be investigated acoustically at the same time as the collection of still and video camera images. During recent cruises to the Arctic (PS101; Boetius and Purser 2017) and the flanks of the Atacama trench (SO261) the facility for this combined system to generate useful data on geological structure distribution, high-resolution topographical products and faunal distribution maps has been demonstrated.

Macroecological studies

The high diversity of seafloor megafauna in the Weddell Sea has been made apparent from previous camera surveys (e.g. PS81 and PS96 in 2013 and 2015/16, respectively). During PS118, comparable image and video data will be collected from a range of other locations (along transects of approx. 2 km length) to complement these previous findings and investigate the abundance, distribution, composition and diversity of epibenthic megafauna. If feasible, the transects are placed such that different benthic habitats (e.g., small-scale slopes, hills, depressions) are covered. Macro- and megabenthic fauna collected from Agassiz trawl catches will be used to aid identification of the organisms depicted in the seabed images. This “dredged” fauna will be quantitatively classified immediately after the catch according to predefined taxonomic and functional criteria, and these findings will be compared with those originating from the imaging surveys. The combined results will serve as a case study for developing a first general standardisation scheme of Antarctic macro- and megabenthic communities. Depending on ice conditions at the time of the cruise, it is our intention to survey areas covered until recently by ice shelves (see Area 1), as well as areas of Larsen B (area covered less recently by permanent ice, Area 2) and areas of seafloor in proximity to Larsen C (Area 3). Up to 30 deployments are envisaged.

Expected results

Habitat mapping

The collection of the first images and acoustic topographical high-resolution data from regions of seafloor until recently permanently ice covered is envisaged. Should conditions be unfavourable for surveying these regions of seafloor, collecting data from the secondary study targets will supplement the data collected from previous cruises, such as PS81 and PS96, to improve our understanding of habitat distributions in the Weddell Sea.

Macroecological studies

Sampling new sites off the Larsen C ice shelf will allow for a comparative analysis of the ecological impact of the ice-shelf and almost permanent sea-ice cover on benthic communities. Moreover, sampling reference sites outside the Larsen area formerly covered by ice shelves facilitates evaluating the faunal succession the Larsen A, B and C habitats have undergone and will undergo, respectively, after the ice-shelf collapses. Additionally, data will identify spatial distribution patterns at local and regional scales. Finally, results will aid standardising the classification of benthic communities.

Data management

Habitat mapping

All raw video and image data will be uploaded to PANGAEA within 6 months of cruise completion, and made fully open-access within two years of cruise completion, or earlier following scientific paper publication. All acoustic data will likewise be placed in PANGAEA, following geo-referencing within two years of cruise completion. Derived terrain variable maps will be made open access on PANGAEA following use in scientific papers or two years after cruise completion.

Macroecological studies

Faunistic data will be will be publicly available in PANGAEA at latest one year after the cruise, as well as in AntaBIF (Antarctic Biodiversity Information Facility; formerly SCAR-MarBIN), as soon as studies on macro- and megabenthic classification, quantification and identification are finished.

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12. SEA ICE PHYSICS

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Objectives

In contrast to sea ice in the Arctic, the extent of Antarctic sea ice has increased by 3.0 % per decade in summer and by 0.9 % per decade in winter since 1979 (e.g., Parkinson and Cavalieri 2012; Simmonds 2015). However, there is large interannual variability and there are large regional differences. In particular, sea-ice extent in the Weddell Sea has slightly declined during winter, but strongly increased during summer (Turner et al. 2014; Hobbs et al. 2016), leading to increasing amounts of thick, second-year ice. While Antarctic-wide changes of sea-ice extent and in particular variations in the Ross, Amundsen, and Bellingshausen Seas have been linked to variations of stratospheric circulation related to ozone depletion, and its imprints on surface winds (e.g., Turner et al. 2009; Thompson et al. 2011) or to the freshening of the Southern Ocean due to increased bottom melt of ice shelves (e.g., Bintanja et al. 2013), there is little understanding of the underlying reasons for the observed changes specifically in the Weddell Sea. Interpretation is further hampered by a lack of observational data of ice drift and thickness required for better model development, interpretation, and prediction. The study region of PS118, i.e. the western Weddell Sea, is a key region in this regard, as it is the region hosting the remaining sea ice during summer. Therefore, PS118 provides unique opportunities to better study the thickness, properties, and drift in this region to unravel the causes of increased summer ice extent and the special role of the Weddell Sea's sea ice cover in Antarctica. One of the key questions is if ice extent has increased due to increased advection of ice to the North, or due to increased ice thickness which protects the ice from early melt.

The planned work builds on previous work carried out by early *Polarstern* cruises in the 1990s (e.g. Lange and Eicken 1991), as well as during the ISPOL (Hellmer et al. 2008; Haas et al. 2008) and WWOS cruises (Haas et al. 2009; Tan et al. 2012) in 2004 and 2006, respectively. Ice thickness and satellite radar data showed the presence of variable ice types depending on their origin, age, and oceanic regime, which also had distinctly different thickness distributions. Some of the perennial ice in the West was thicker than 3 m and rivaled the thickest ice in the Arctic. There were no other ice thickness observations since then, except for an airborne survey of snow thickness by NASA (Kwok and Maksym 2014).

It is therefore the aim of the sea-ice physics' project on "Sea ice properties and processes in the western Weddell Sea" (WedIce) during PS118 to continue ice thickness observations and radar remote sensing and to compare them with results from earlier cruises to detect and quantify potential change. The thickness of different ice regimes will also be related to different oceanic regimes with different magnitudes of ocean heat flux (Hellmer et al. 2011). Due to the timing of PS118 in February to April, results will represent end-of-summer minimum ice conditions and will help to explain the area and amount of ice surviving the summer. This will provide important background information on the state of sea ice in the Weddell Sea and the reasons for its long-term changes. As the ship will pass from the open water through the MIZ into the closed pack ice zone it will also be possible to observe meridional and zonal gradients of ice thinning and snow melt representing the changing influence of atmospheric and oceanic melt processes (Rabenstein et al. 2010).

Another important component of the sea ice mass balance is the accumulation and metamorphism of snow (Massom et al. 2001; Haas et al. 2001). Thaw-freeze events and snow metamorphism can be detected by satellite microwave observations (Haas 2001; Arndt et al. 2016), thus providing valuable insights into the timing and change of melt onset related to changing atmospheric conditions. Melt onset is also related to ice thickness because earlier and stronger surface melt will accelerate overall thinning. During PS118, we plan to validate satellite microwave retrievals of metamorphic snow and to investigate if regional gradients in the intensity of metamorphism can be detected by satellite microwave sensors.

One consequence of downward heat flux and snow thaw is the percolation of melt water to the snow-ice interface and the formation of gap layers, continuous or highly porous layers in the upper ice filled with seawater or slush and high amounts of algae and other micro-organisms (Thomas et al. 1998; Haas et al. 2001; Kattner et al. 2004; Ackley et al. 2008). The relationships between the thickness and biomass and other biogeochemical properties of gap layers and the overlying superimposed ice and degree of snow metamorphism have never been investigated. Therefore, the WedIce projects aims to focus also on such interdisciplinary studies, given that we expect strong gradients in experienced melt conditions during summer across the marginal ice zone.

Moreover, the western Weddell Sea is characterized by the presence of fast ice located in inlets and bays adjacent to the Larsen ice shelves. Some of this fast ice can survive several summers and then cause reductions of iceberg calving and stabilization of glaciers (Rott et al. 2017). The fast ice is also of interest because it can accumulate platelet ice, an indicator for the presence of Ice Shelf Water and therefore of ice shelf bottom melt (Langhorne et al. 2016). We therefore aim in the WedIce project to observe the thickness of fast ice where it has survived the summer, the role of snow for summer survival, and the presence of platelet ice within and under the fast ice. Of particular interest are the fast ice in the Larsen B embayment and between the Larsen C ice shelf and iceberg A-68.

Work at sea

Helicopter-based ice thickness surveys

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

Snow and ice sampling

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

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

On board

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

Preliminary (expected) results

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

- Observations of the thickness distribution of different ice regimes in the western Weddell Sea in relation to their deformational history and oceanic heat regimes
- Comparisons of ice thickness results with previous results from the same region (ISPOL 2004 and WWOS 2006 cruises) to observe long term ice thickness changes
- Observations of snow properties and the degree of snow metamorphism to evaluate the intensity of snow melt during the preceding, 2018/19 summer, and for improvement and validation of radar and passive microwave remote sensing retrieval algorithms
- Observations of thickness of superimposed ice and gap layers in relation to the observed intensity of snow metamorphism and melt
- Observations of biogeochemical properties, DNA, and microplastics at the bottom of superimposed ice and in the gap layer

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 WedIce to be available within a maximum of two years after completion of the expedition. Buoy data will be available in nearreal time through the online portal www.meereisportal.de, and will be embedded into different international data bases, as through the International Program for Antarctic Buoys (IPAB).

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13. ROLE OF MEIO- AND MACROFAUNA IN BENTHIC ECOSYSTEM FUNCTIONING: TESTING EFFECTS OF ICE SHELF LOSS

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Objectives

Observed changes in benthic community composition and benthic food supply on the Larsen Shelf after the collapse of large portions of the Larsen A and B Ice Shelves (Gutt et al. 2011) raise the question whether this may have influenced benthic ecosystem functioning (BEF). Important BEF components are the degradation of organic matter and associated remineralization of carbon and inorganic nutrients and bioirrigation.

Following the recent calving from the Larsen C Shelf the seafloor underneath the former ice-covered area can be assumed to start undergoing previously observed changes from Larsen A and B. It is not known if and how this development influences the processes at the seafloor, the benthic functions. For a comprehensive understanding of ecosystem functioning it is, hence, necessary to determine the role of different ecosystem components. Our focus is on the effect of macrofauna and meiofauna on seafloor processes in areas having lost ice-shelf cover at different times.

Few studies have investigated different size classes and communities of organisms, like meio- and macrofauna, in this benthic environment simultaneously. And on the Southern Ocean shelves, none has studied their complementary role for benthic remineralisation and bioirrigation. Influences of reduced or changing ice cover on trophic interactions among and the relative importance of meio- and macrofauna taxa are not understood. How benthic boundary fluxes (nitrate, phosphate, silicic acid, oxygen) and bioirrigation are affected by ice-shelf loss in the Weddell Sea is unknown. And virtually nothing is known about the partitioning of organic matter remineralisation between the meiobenthic and macrobenthic community compartment in the Southern Ocean. During the PS118 expedition, we intend to study the role of macro- and meiofauna for benthic processes. The trophic interaction between macro- and meiofauna using stable isotopes will be studied in collaboration with colleagues from the University of Aberdeen (TABOSI, Witte & Makela).

The objectives for this expedition are:

1. Quantify benthic remineralisation and bioirrigation in Larsen area with and without ice-shelf loss (reference)
2. Determine the effect of meio- vs macrofauna (and organic matter input) on benthic remineralisation and bioirrigation in
   a) ice-shelf loss affected and b) reference sites
3. Determine the trophic interaction of meio- and macrofauna in areas affected by ice-shelf loss

Work at sea

In general, we will use sediment cores collected by the multicorer MUC10 and water from the rosette water sampler at two depths (closest to the bottom and at the fluorescence maximum) for the work on board.

We intend to take samples at a total of 16 sites with 5 sediment core replicates per site. To test the factor 'ice-shelf loss' (time) we plan 4 sites each in the following areas: former A-68 shelf (ice-shelf loss, t1), east of Larsen C (reference), shelf north of Larsen C (reference), Larsen B ('west') (ice shelf loss, t2).

According to the objectives presented above, we will conduct field experiments (incubation of sediment cores with inhabiting meio- and macrofauna) for collecting samples of faunal communities, benthic boundary fluxes, bioirrigation and stable isotope composition (BEFEx, Link et al. 2016). BEFEx experiments are based on ex situ incubations of sediment cores with overlying water (Link et al. 2013): Oxygen and nutrient concentrations are measured in the overlying water column over the incubation period of 2-6 days. A Fibox-LCD optical sensor is used to determine oxygen concentration non-invasively. During PS118, we will trace bioirrigation by adding NaBr to the water overlying the cores and subsequent sampling in the sediment pore water. At the end of incubations - usually when oxygen concentration had decreased by 20 % - sediment cores are sliced and preserved in 4 % formaldehyde-seawater solution (borax-buffered) for later meio- and macrofaunal analyses. Subsamples for pore water extraction will be frozen for later analysis of NaBr concentration.

Further, we will collect untreated samples for the following parameter groups at each station:

- Habitat factors of the sediment (chlorophyll-a and phaeopigments, grain size, sediment stable isotopes $\delta^{13}C$ and $\delta^{15}N$)
- Fauna natural stable isotopic composition (from sliced sediment cores) to compare with TABOSI results (University of Aberdeen)
- Environmental factors of the water column (chlorophyll-a and phaeopigments, stable isotopes $\delta^{13}C$ and $\delta^{15}N$

Moreover, we will study the benthic boundary fluxes and partitioning of organic matter uptake by meio- and macrofauna in collaboration with the TABOSI project (Witte & Makela) conducting ex-situ ITEs.

We plan to carry out MUC10 deployments at stations where bottom topography will allow safe use of the gear. We will collect information on sediment composition and bottom topography from the bathymetry group (Dorschel et al.) and by following the OFOBS deployment (Ocean Floor Observing and Bathymetry System, Purser et al.).

Expected results

By combining faunal size classes and different benthic processes synchronously, it will be possible to evaluate, what the net ecological effect of ice shelf loss on the Weddell Sea benthic system could be. In addition to the integration with food web structure findings (TABOSI), our results will also complement macroecological findings (Purser et al.) from PS118.

Data management

Most data will be obtained through laboratory analyses after the cruise. Processed data will be uploaded to the databases PANGAEA and/or SCAR-MarBIN.

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N.N.		Heli Service Int	
N.N.		Heli Service Int	

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2.	Grundmann, Uwe	1.Offc.
3.	Westphal, Henning	Ch.Eng.
4.	Fischer, Tibor	2.Offc.Lad.
5.	Hering, Igor	2.Offc.
6.	Peine, Lutz	2.Offc.
7.	Jaeger, Norbert	Doctor
8.	Dr.Hofmann, Jörg	Comm.Offc.
9.	Schnürch, Helmut	2.Eng
10.	Brose. Thomas	2.Eng.
11.	Rusch, Torben	2.Eng.
12.	Brehme, Andreas	Elec.Tech.
13.	Frank, Gerhard	Electron.
14.	Markert, Winfried	Electron.
15.	Winter, Andreas	Electron
16.	Feiertag, Thomas	Electron
17.	Sedlak, Andreas	Boatsw
18.	Neisner,Winfried	Carpenter
19.	Clasen, Nils	AB.
20.	Schröder, Norbert	AB.
21.	Burzan, Gerd-EkkehardAB.	
22.	Hartwig-Labahn, Andreas AB.	
23.	Fölster, Michael	AB.·
24.	Müller, Steffen	AB.
25.	Brickmann, Peter	AB.
26.	Schröder, Horst	AB.
27.	Beth, Detlef	Storekeep.
28.	Plehn, Markus	Mot-man
29.	Waterstradt, Felix	Mot-man
30.	Krösche, Eckard	Mot-man
31.	Dinse, Horst	Mot-man
32.	Watzel, Bernhard	Mot-man
33.	Meißner, Jörg	Cook
34.	Tupy,Mario	Cooksmate
35.	Martens, Michael	Cooksmate
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38.	Hischke, Peggy	2.Stwdess
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42.	Chen, Quan Lun	2.Steward
43.	Ruan, Hui Guang	Laundrym.
44.	Erlenbach, Colin	Trainee1.LJ
45.	Krumrei, Benni	Trainee 1.LJ