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HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

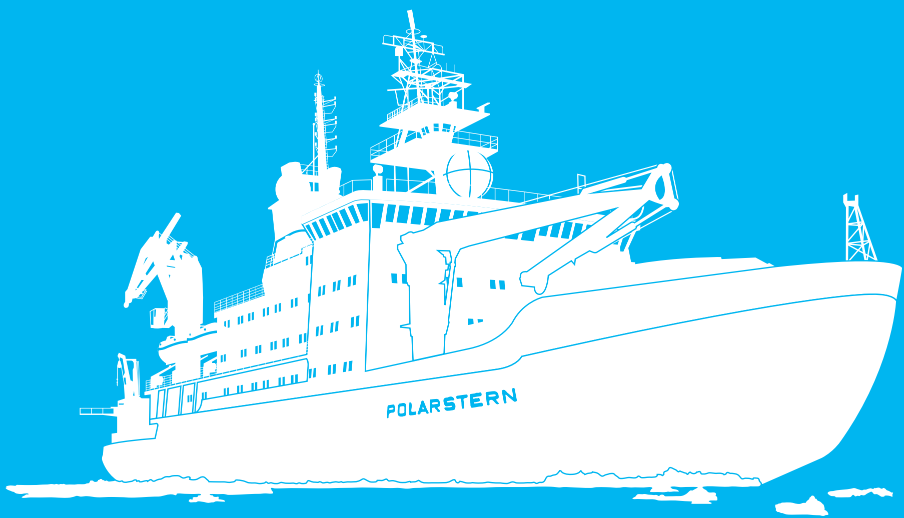
EXPEDITION PROGRAMME PS133/2

Polarstern

PS133/2
Punta Arenas - Cape Town
19 November 2022 - 19 December 2022

Coordinator: Ingo Schewe

Chief Scientist: Sabine Kasten



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The Programme provides information about the planned goals and scientific work programmes of expeditions of the German research vessel *Polarstern*.
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Expedition PS133/2 / IslandImpact Leg 2

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Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Sabine Kasten[1] [1]DE.AWI

Hauptziel der Expedition PS133/2 „Island Impact“ an Bord von *Polarstern* ist es, die Quellen und Transportwege von Eisen (Fe), weiteren Nährstoffen (sowohl Makronährstoffe als auch Spurenelemente/-metalle) und Kohlenstoffverbindungen in die Schelfgewässer der Insel Südgeorgien und weiter stromabwärts in den südlichen antarktischen Zirkumpolarstrom (ACC) zu verstehen. Wir werden daher die wichtigsten von der Insel stammenden (Schelf-)Quellen von Fe, Nährstoffen und anderen Spurenelementen untersuchen, einschließlich der Auswirkungen des Eintrags dieser Verbindungen durch das Ausströmen von Methanblasen und das Austreten subaerischen und submarinen Grundwassers. Methan-Ausstritte, Grundwasseraustritte, Oberflächenwasserabfluss und Sedimente können alle eine Rolle spielen. Zu den Arbeiten gehört auch die Untersuchung der Frage, wie das im Arbeitsgebiet weitverbreitete Austreten von Methan die benthischen Faunengemeinschaften sowie den Materialumsatz und die Elementflüsse steuert. Darüber hinaus untersuchen wir, wie das von den Inseln stammende Fe und andere potenzielle Fe-Quellen zur Biogeochemie und Ökosystemstruktur im atlantischen Sektor des Südlichen Ozeans beitragen.

Um verschiedene Quellen und Transportmechanismen von Fe, Nährstoffen, Spurenmetallen und Kohlenstoffverbindungen in die Schelfgewässer von und vor Südgeorgien identifizieren zu können, werden wir den Cumberland Bay Fjord und den King Haakon Bay Fjord sowie die damit assoziierten Tröge als Hauptarbeitsgebiete nutzen. Diese werden als „Modellgebiete“ dienen, um hochauflösende multidisziplinäre Untersuchungen sowohl in der Wassersäule, im Sediment und teilweise auch in der Atmosphäre durchzuführen. Diese beiden Fjorde/Tröge wurden ausgewählt, da sie sich in Bezug auf die potenzielle Herkunft des Methans (biogen vs. thermogen), die Stabilität der Gashydrate und die Kohlenstoffquellen unterscheiden (z.B. fand in Grytviken im Cumberland Bay Fjord Walfang statt, nicht aber in der King Haakon Bay). Darüber hinaus werden wir mit einem Schlauchboot Wasser- und Sedimentproben in Küstennähe (außerhalb der Reichweite der *Polarstern*) nehmen und in ausgewählten Fjorden auch an Land arbeiten, um Boden-, Grund- und Schmelzwasserproben sowie Vegetationsproben zu gewinnen. Diese Proben werden zur Identifizierung von Endgliedern und zur Bestimmung der Zusammensetzung von partikulären und gelösten Verbindungen in den verschiedenen Quellgebieten verwendet.

Die Arbeiten in den beiden oben genannten Hauptuntersuchungsgebieten werden durch Arbeiten entlang schelfparalleler Transekte – einschließlich des Transits nach und von Südgeorgien – und zusätzliche Arbeiten im Church Trog und Drygalsky Fjord und Trog (siehe Karte B) sowie an Land in Jason Harbour, Husvik und Sorling ergänzt (Abb. 1.1 und Abb. 1.2).

SUMMARY AND ITINERARY

The main aim of expedition PS133/2 “Island Impact” on board of *Polarstern* is to understand the sources and transport pathways of iron (Fe), other nutrients (both macronutrients and trace elements/metals) and carbon compounds into South Georgia Island shelf waters and further downstream in the Southern Antarctic Circumpolar Current (ACC). We will, therefore, investigate the main Island-derived (shelf) sources of Fe, nutrients and other trace elements including the impact of injection of these compounds by methane bubble ebullition and groundwater seepage. Seeps, groundwater, runoff and sediments may all play a role. Work also includes the study of how methane seepage controls benthic faunal communities as well as material turnover and element fluxes. We further investigate how this local island-derived Fe and other potential Fe sources contribute to the downstream biogeochemistry and ecosystem structure in the Atlantic sector of the Southern Ocean.

In order to identify different sources and transport mechanisms of Fe, nutrients, trace metals and carbon species into the shelf waters of and offshore South Georgia we will use the Cumberland Bay Fjord and the King Haakon Bay and associated troughs as main working areas. These will serve as “model areas” to perform high-resolution multidisciplinary investigations both in the water column, in the sediment and partly also in the atmosphere. These two fjords/troughs have been chosen because they differ with respect to potential origin of methane (biogenic versus thermogenic), gas hydrate stability and carbon sources (e.g.; whaling took place at Grytviken in Cumberland Bay fjord but not in King Haakon Bay). Furthermore we will use a zodiac to sample water and sediments close to shore (outside the reach of *Polarstern*) and also work onshore in selected fjords to sample soil, groundwater, meltwater and vegetation. These samples will be used to identify endmembers and to determine the composition of solid and dissolved compounds in the different source areas.

The work in the two main study areas mentioned above will be complemented by work along shelf-parallel transects – including transit to and from South Georgia – and additional work in the Church Trough and Drygalsky Fjord and Trough (see Map B) as well as on shore sites in Jason Harbour, Husvik and Sorling (Fig. 1.1 and Fig 1.2).

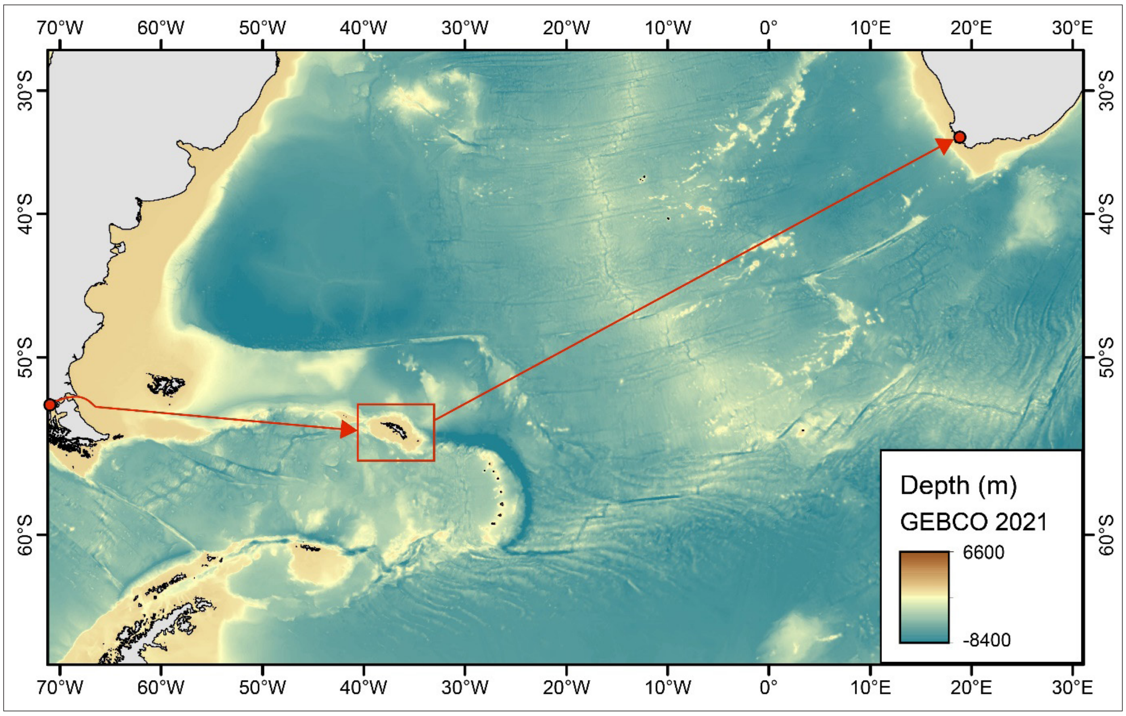

Abb. 1.1: Fahrtroute der Expedition PS133/2
Fig. 1.1: Cruise track of expedition PS133/2

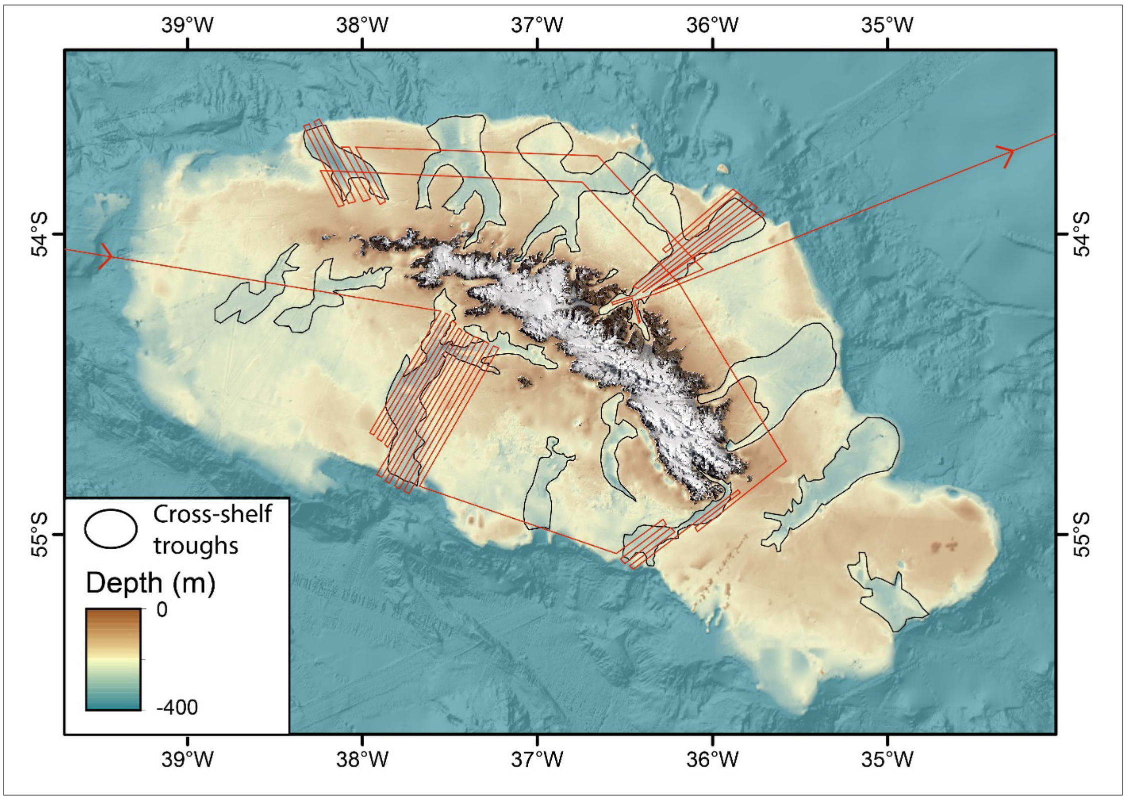

Abb. 1.2: Arbeitsgebiete und Vermessungs- und Beprobungstransekte im Bereich Südgeorgien
Fig. 1.2: Study areas and mapping and sampling transects in and around South Georgia

2. HYDROACOUSTIC INVESTIGATIONS ON GAS EMISSIONS

Katharina Streuff[1], Nina Lesic[2], Neele Köhler[1], Catalina Rubiano[3]
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Grant-No. AWI_PS133/2_01

Objectives

Actively emitting gas bubble seepage was first detected and described around South Georgia during a *Polarstern* expedition in 2013 (Bohrmann et al., 2013). Although such sources have been detected in numerous regions in our oceans, these are the first active seeps found south of the Antarctic Polar Front. Although only a few surveys were possible near South Georgia during this cruise, a total of 133 gas seeps were detected using the hydroacoustic systems. Correlation of the seep locations with the bathymetry of the shelf was enabled by the compilation of the extensive ship-based echosounder data published by Graham et al. (2017). Initial interpretations of the distribution of these detected gas bubble seeps indicated that emissions were found exclusively in areas of glacial troughs along the shelf and within fjords (Römer et al., 2014). Analyses revealed that the gas bubbles contained almost only methane, which was produced by microbial decomposition of organic material (Geprägs et al., 2016).

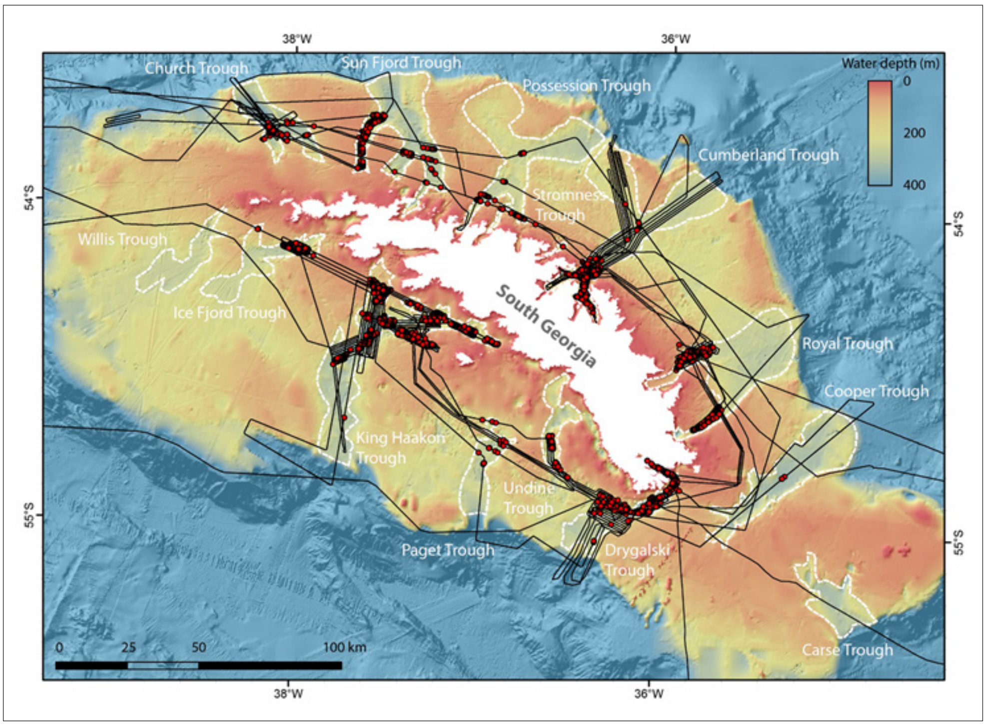

Fig. 2.1: Bathymetric representation of the shelf area around South Georgia; glacial troughs cut into the shallow shelf (white dashed areas); thousands of gas bubble seeps (red dots) were detected during two expeditions (black lines).

More intensive investigations of this newly discovered gas system were undertaken in 2017 during the *RV Meteor* expedition M134 (Bohrmann et al., 2017). This involved the systematic investigation of gas seeps in eight shelf troughs around South Georgia. A total of 2,647 nmi around South Georgia were mapped with sediment echosounder and multibeam echosounder. Several thousand gas seeps were detected as acoustic anomalies in the water column (Fig. 2.1). Almost all of the seeps were found to correlate with gas accumulations in the sediments, and again, to be concentrated mainly in the inner fjord systems and glacial troughs, where there is increased deposition of organic matter and increased microbial methane production.

Both singlebeam, splitbeam, and multibeam data include water column information about active gas seeps and can visually represent them. The splitbeam data can also be used to quantify flow rates. The sediment echosounder provides additional data about gas sources but also gas concentrations and their pathways in the shallow subsurface. Bathymetry and backscatter maps generated by the multibeam will also help to identify and characterize morphological structures associated with gas seeps. The following questions will be investigated:

- How much gas (almost exclusively methane) escapes around South Georgia?
- How variable are these seeps, i.e. what kind of fluctuations do we have to expect that need to be included into a quantification approach?
- How are the gas emissions distributed and what distribution patterns can be observed? In order to achieve an overall estimate of gas emissions from individual measurements we have to extrapolate. This in turn will only be realistically possible if the distribution patterns are known.

Work at sea

During the cruise, we will follow a shift-watch system so that the hydroacoustics room will be manned throughout. The instruments can thus be looked after around the clock and failures can be remedied immediately. In addition, data preparation and processing will be done directly on board, so that promptly after data acquisition all information will be available in a geo-information system for further cruise planning and interpretation.

Application of the planned investigation methods:

1. Atlas Parasound singlebeam:
   Acquisition of two frequencies, for sediment profiles and water column anomalies.
   Data will be displayed and processed using Kingdom Suite software.
2. Atlas Hydrosweep multibeam:
   Creating bathymetry and backscatter maps using MB-Systems software.
   Mapping of water column anomalies (gas emissions).
   Plotting and processing these data using QPS Fledermaus software.
3. Simrad splitbeam Echosounder:
   Uses 4 frequencies, with 38 kHz being the most appropriate for visualizing gas bubbles in the water column (at these water depths). The system can also be used to quantify the amount of gas flow (Veloso et al., 2015).
4. Sound velocity probe:
   Necessary for the correction and processing of the hydroacoustic systems.
5. Posidonia navigation system:
   Transponder for accurate positioning of seafloor sampling. Activation, functionality during deployments, and data evaluation of correct sampling position are done by the team's person on watch.

6. Geographic information systems:
   Representation of acquired data in geographic information systems to create maps, define sampling, interpret results.

7. Data backup:
   Storage of all acquired data on board and long term archiving after departure ashore.

Expected results

We expect to be able to achieve a better understanding about the gas system around South Georgia. Missing data to allow a quantification of released gas from the shelf as well as important information about variability and distribution pattern of the gas emissions will be collected. With this data, we aim to provide the total amount of methane released into the water column around South Georgia.

Data management

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

The data obtained during the cruise for this project will first be stored on hard disks to be brought ashore. After the cruise, they will be saved on the servers available for this purpose at MARUM and finally archived at PANGAEA long-term, provided with DOIs and made available for further scientific analysis after a moratorium period of three years.

Data	Estimated volume	Archiving
Parasound (ATLAS)		
KingdomSuite Project	2 TB	
*ASD, *PS3, *SEGY data files:	0.5 TB	1 month after cruise
3.5 kHz frequency (sediment profiles)		MARUM und PANGAEA
19 kHz frequency (water column)		Open access after 3 years
Multibeam (HYDROSWEEP)		
Bathymetry raw data	1 TB	1 month after cruise
Water column raw data	2 TB	1 month after cruise
Grids, prozessed data	0.5 TB	1 month after cruise
		MARUM und PANGAEA
MB-Systems Projects	2 TB	Open access after 3 years
QPS Fledermaus Projects	2 TB	
Splitbeam (SIMRAD)		1 month after cruise
38 kHz Frequenz raw data	1 GB	MARUM und PANGAEA
		Open access after 3 years

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

This expedition is supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 2, Subtopic 1, Topic 4, Subtopic 1 and Topic 6, Subtopic 3 and additional funding by MARUM – Center for Marine Environmental Sciences, University of Bremen to Project "Hydroacoustic Island Impact".

In all publications based on this expedition, the **Grant No. AWI_PS133/2_1** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. http://dx.doi.org/10.17815/jlsrf-3-163.

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Veloso M, Greinert J, Mienert J and De Batist M (2015) A new methodology for quantifying bubble flow rates in deep water using splitbeam echosounders: Examples from the Arctic offshore NW-Svalbard. Limnol. Oceanogr. Methods, 13:267–287. http://dx.doi.org/10.1002/lom3.10024

3. MARINE GEOLOGY

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Grant-No. AWI_PS133/2_02

Objectives

Because of its unique location in the Southern Ocean, the island of South Georgia is superbly situated to study the climatic and oceanic forcing of sub-polar environments over various timescales (Rosqvist, 1999). Described as a 'sentinel for change' in the Southern Hemisphere (Graham et al., 2017), the island's ice cap is extremely sensitive to environmental perturbations and therefore detailed records of how it has changed over time and space can provide important insights into past climatic changes (Gordon et al., 2008). In addition, because the South Georgia serves as a scaled-down analogue for a marine-terminating ice sheet, the dynamics and behaviour of the ice cap can provide valuable clues as to how the larger Antarctic Peninsula ice sheet may respond to future environmental changes as the ocean and atmosphere of the polar regions warm. Unlike many other regions of the polar Antarctic, the South Georgia ice-cap's fjords are shallow, typically ice-free in summer, and accessible by ship, meaning they are easily mapped at high-resolution with sonars, and sediments there are readily obtainable (Hodgson et al., 2014). The sediments within the fjords are locally thick owing to a high sediment flux from the island's glacial systems and glacial turnover is fast, meaning the time between changes in the glacier catchments and time of deposition at the sea bed is often negligible. As such, these sub-polar marine environments provide ideal natural laboratories for studying glacial sedimentation processes, the processes of landform generation, as well as detailed studies of glacial outputs including assessing temporal changes in ice and sediment flux, as well as meltwater dynamics.

Previous studies combining marine geophysical observations and marine sediment core records focused on reconstructing the extent of the Last Glacial Maximum ice cap, which is now widely believed to have terminated at or very near to the shelf break (Graham et al., 2008; 2017; Barnes et al., 2016; Barlow et al., 2016) linked to South Georgia's modern-day fjords, radiate from the island, marking the former pathways of large outlet glaciers and ice streams. A tectonic or geological influence is apparent for the major troughs, where glaciers have exploited structural weaknesses on the continental block. Bed forms lining the troughs give some first insights into glacial dynamics within the troughs, suggesting arteries of fast flowing ice occupied these topographic depressions in the past and operated over both bedrock and sedimentary substrates. On the outer shelf and within the troughs, large ridges and banks are also common, interpreted as terminal, lateral, and recessional moraines marking former positions of ice sheets on the shelf and their subsequent reorganization during deglaciation. A small trough mouth fan has developed at the mouth of at least one of the cross-shelf troughs, demonstrating a focused sediment delivery to the margin. Slides and slide scars are also present on parts of the margin, showing that margin stability, perhaps also related to glaciation, has been an important factor in depositional processes on the continental slope. Implications of the new observations are that ice sheets have been more extensive on South Georgia than any previous studies have reported. Their age may date back to late Miocene times, and evolution of the shelf system has probably involved numerous late Cenozoic glacial episodes. However, relatively fresh seafloor geomorphology coupled with evidence from other maritime-Antarctic islands (Heard Island and Kerguelen Island – as such, the ice cap was significantly larger than it is today. The subsequent retreat of the ice cap is recorded in well-preserved morainal banks, subglacial bedforms, and stepped moraine sequences that show a net overall recession of ice margins along cross-shelf troughs, and across shallower banks, to the modern coastline (Graham et al., 2017). Several readvances of the ice cap are inferred from prominent sea-floor moraines that are mapped regionally in the same physiographic position from one fjord to the next (Hodgson et al., 2014). One of these moraine positions, at the mouth of topographically-constrained fjords, is believed to correlate to an ice-cap wide readvance during the Antarctic Cold Reversal (c. 14.7–13 ka B.P; (Pedro et al., 2016)), demonstrating a sensitive glacial response on the island to abrupt hemispheric-scale climatic shifts during the last deglaciation. The Holocene environmental record of glacier change is better constrained. Onshore geological records describe numerous readvances of terrestrial glaciers during the last 10,000 years, possibly driven by changes in the position of the South Westerlies (Oppedal et al., 2018; Bakke et al. 2021). However, the same records are not well resolved for the offshore environment despite high potential for such events to be archived in the fjord sediments.

Despite significant improvements in knowledge of the ice cap history, the understanding of glacial change on South Georgia is still rudimentary when compared against our knowledge of glacial variability from other geographic locations in the Antarctic (Bentley et al., 2014). One question that remains unanswered is whether the morainal sequences at the heads of inner and outer shelf basins around the island are co-temporaneous, and hence all record the same climatic episodes, or whether their positions mark topographically-controlled stillstands (e.g. Åkesson et al., 2018) at different points during the ice cap deglaciation (Graham et al., 2017). Another question that remains open concerns the existence and extent of fringing ice shelves around the ice cap as it retreated. The presence and persistence of shelf-ice cover potentially has important implications for the productivity history of the South Georgia margin, as well as the location and survival of sea-floor biological refugia through past glacial episodes (Barnes et al., 2016). Likewise, the role that meltwater played in past ice flow, in bed shaping, and in forcing glacier retreat is still not well constrained despite good evidence for abundant meltwater landforms at the sea bed. Additionally, we have a poor understanding of glacial-interglacial cycles pre-dating the LGM, including a lack of knowledge about how the acoustic stratigraphy of the shelf relates to Quaternary cycles of ice-cap waxing and waning. Recent work has also hypothesised that buried peats are present within some of the island's glacial fjords, raising the possibility that sections of the submerged sea-floor were subaerial during past sea-level lowstands, and now serve as the source of methane which vents at the sea bed (Geprägs et al., 2016). Each of these questions can be addressed by new reconstructions of ice-cap and palaeoenvironmental change from the sea-floor morphological, subsurface geophysical, and sedimentary archives from the South Georgia continental block.

Over the last 100 – 150 years, glacier recession across most of the island has been recorded by visual and satellite observations (Cook et al., 2010), with rapid glacier retreat since at least the 1970s. However, the timing of when rapid ice retreat was instigated, and in response to which external forcings, remain open questions. This could be addressed by obtaining high-resolution coastal records from diatom-bearing marine muds near to the glacier margins. Because PS133/2 will study two troughs, one either side of the island, there is significant opportunity to assess spatial patterns of ice-cap change by way of comparison, in addition to whether glacier retreat has been driven primarily by atmospheric (e.g. Fohn winds) or oceanic drivers, as well as anthropogenic or natural components of the climate system (e.g. SAM or the South Westerlies). Finally, although the ice cap is relatively small, the island is strategically located between oceanographic frontal systems that result in its marine geological record providing an outstanding archive of regional palaeo-oceanic variability. From shelf cores, there is potential to not only deduce the glacial history of the region, but also to provide insights into regional palaeoceanography including flow intensity of the ACC and latitudinal migration of the Polar Front.

Work at sea

The main goal of the marine geology work package addresses the objective of the *IslandImpact* proposal 'to reconstruct depositional history related to glacial/interglacial variations in sedimentation regimes'.

The marine geoscientific work on the expedition will concentrate on five targets. Each of these contributes towards improved knowledge of South Georgia sea-floor environments, sedimentary regimes, and the physical processes that have influenced the marine environment over time.

1. Coring information to support Hydrosweep swath bathymetry and Parasound sub-bottom profiler data that will add new high-resolution bathymetric information on glacial morphology and shelf sequence stratigraphy, and serve as a foundation to sea-floor geomorphic interpretations (see hydroacoustics chapter for further information).
2. Long and surface sediment cores will be collected by means of a gravity corer (GC) and multiple corer (MUC) in order to recover sedimentary sequences that can be used to reconstruct the glacial history of the island since the Last Glacial Maximum.
3. Sediment coring on an opportunistic basis near to methane seeps or along glacier fronts to provide temporal and local environmental information.
4. Test the idea that peats are buried in the glacial fjords of South Georgia and may be the source loci of modern-day methane venting
5. Contribute to the wider understanding of sources of Fe to the continental shelf through improved understanding of modern glacial processes and past environmental variability.

Although we are a marine geological team, we will integrate seemlessly with the hydroacoustics team onboard *Polarstern*, and share our expertise amongst the groups. Sediment coring cannot be carried out in isolation. Our coring sites will be guided by sub-bottom profiles obtained using the hull-mounted Parasound profiler on *Polarstern*, and by contextual geomorphological interpretation of corresponding newly-acquired multibeam bathymetry.

Sediment surface samples will be collected in addition to longer sediment cores by means of a giant box corer (GKG) and multiple corer (MUC), as well as a gravity corer (GC). Processing onboard will involve splitting, multi-sensor core logging using a GEOTEK core logger (principally for magnetic susceptibility), photography, detailed sediment description, and sub-sampling. An archive half will be preserved with a working core half the subject of subsequent analysis. Samples will be collected specifically for grain size analysis, TOC, and sediment dating, following protocols established by the AWI marine geological group.

We anticipate collecting cores in each trough, targeting a transect of moraines, landforms, and sedimentary units that each record the progression of glacial change along each trough. We will split and sample up to 50 % of the cores onboard if time allows. Several proximal MUC cores will be sampled in 1cm steps for palaeoceanographic studies of recent centennial glacier change. We will also sample for Pb-210 at these sites. Surface samples at each GC location will be taken for constraining the surface age.

Any opportunity to survey using multibeam water-column imagery along the modern ice fronts would allow us to establish whether there are modern-day sediment and meltwater plumes emanating from the glacier margin, and to interpret their dynamics.

After the cruise, marine geological and marine geophysical (bathymetry, backscatter, sub-bottom) information will be combined to provide holistic interpretations of depositional environments on the South Georgia block.

Expected results

We expect to be able to provide results on the following aspects of South Georgia's depositional environments:

- Improved geomorphological and geological characterization of sea-floor glacial systems, providing insight into past ice flow and retreat dynamics
- New sub-surface stratigraphic interpretations for at least two troughs, integrated with interpretations from existing sub-bottom datasets acquired on previous cruises to the region.
- Well-dated sedimentary sequences recording the retreat of glacial systems either side of South Georgia during the last deglaciation and through the Holocene
- Dates for the outermost moraine systems on the continental block, to verify the terminal limit and timing of maximum expansion of the LGM ice cap.
- Test of the 'ACR hypothesis' for fjord mouth moraines in at least one new location
- Image, isolate, and attempt to core buried peat deposits in South Georgia troughs, using a combination of sediment echo-sounding and gravity coring.
- High-resolution environmental reconstructions for the last two centuries from ice-proximal sites north and south of the island, using multi-proxy and isotopic signatures.

Data management

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

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

This expedition is supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 2, Subtopic 1, Topic 4, Subtopic 1 and Topic 6, Subtopic 3.

In all publications based on this expedition, the **Grant No. AWI_PS133/2_02** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. http://dx.doi.org/10.17815/jlsrf-3-163.

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4. SEDIMENT GEOCHEMISTRY

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Objectives

Our main objective is to determine and quantify the different sources and transport pathways of iron (Fe), other nutrients (PO_4, NO_3, H_4SiO_4) and trace metals into the fjords and coastal area off South Georgia. Possible sources and transport pathways of dissolved Fe, nutrients and trace metals include a) weathering and erosion of Fe-rich rocks, b) glacial melt, c) submarine groundwater discharge, d) post-depositional reduction and diffusion of Fe across the sediment/water interface, e) dust input and f) mixing of Fe-rich pore water into the water column by means of methane bubble ebullition and bioturbation/bioirrigation.

Sediment investigations performed in Cumberland Bay Fjord and other fjords of South Georgia have revealed high levels of dissolved Fe and PO_4 concentrations in surficial and sub-surface pore-waters of sediments high in methane and affected by active bubble ebullition (Kasten et al., in prep.). Hydrocarbon seepage – both in the form of fluid migration and ebullition of free gas – can exert a strong control on the transport mode and fluxes of elements across the sediment/water interface (e.g., Wallmann et al., 1997; Torres et al., 2003). The ebullition of free gas can produce a mixing of solutes and sediments – similar to bioturbation (e.g., Haeckel et al., 2007), which might represent an important pathway for transferring interstitial constituents into the overlying bottom water. The effect of hydrocarbon seepage on enhancing solute mixing and element fluxes from the seabed into the water column was shown for Ba, Ca, CO_2, DIC and silica (e.g., Wallmann et al., 1997; Torres et al., 2003). However, nothing is known about how and to which extent fluid seepage or mixing induced by the escape of gas bubbles affect the transport, speciation and fate of macro and micro nutrients and other interstitial constituents (Fe, NO_3, PO_4, trace metals) from the pore water into the overlying water. We postulate that abundant bubble ebullition as found in the fjords and troughs of South Georgia and other fjords and troughs of the archipelago might represent an important - yet unconsidered – transport mechanism for Fe and other interstitial constituents across the sediment/water interface, which might be more important than molecular diffusion.

Furthermore, indications of sub-aerial seepage of Fe^{2+}-rich groundwater and subsequent oxidation of Fe^{2+} in contact with atmospheric oxygen in beach areas of the inner Cumberland Bay Fjord were found during expeditions ANT-XXIX/4 and M134 (Bohrmann, 2013; Bohrmann et al., 2017). Groundwater discharge is typically found along many coastal zones worldwide (e.g., Schlüter et al., 2004). It is likely that weathering of the Fe-rich rocks found on South Georgia (Curtis, 2011) and both the sub-aerial and submarine discharge of Fe^{2+}-rich groundwater may represent an important – yet so far mostly unexplored – source and transport pathway of reactive Fe (colloidal, freshly precipitated Fe oxyhydroxide of low crystallinity, or possibly complexed with humic acids) into the coastal zone of South Georgia and most likely other (sub-)Antarctic settings. Therefore, gas bubble-induced solute mixing and transport of interstitial compounds into the water column, and sub-aerial and submarine discharge of Fe^{2+}-rich groundwater represent additional potential sources and transport mechanisms, which have remained relatively unexplored as yet.

There is still uncertainty about the biogeochemical pathways leading to the high levels of dissolved Fe (and PO_4) observed in the pore-waters of the fjord sediments (e.g., Wunder et al., 2021). Thus, another objective is to identify the processes that mediate Fe reduction both in surface sediments and below the sulfate/methane transition (SMT). Possible processes include organoclastic Fe reduction or the methane-mediated Fe reduction, which has been shown in lab experiments (e.g., Beal et al., 2009) and postulated for high-accumulation marine environments (Riedinger et al., 2014; Oni et al., 2015). Identifying the microbial Fe-reducing communities within the sediment (e.g., Oni et al., 2015) will help to answer this question. Stable Fe isotopes have also proven to be valuable tracers to assess the potential sources as well as transport and reaction pathways of Fe – including microbial Fe reduction (e.g. Henkel et al., 2016, 2018).

Work at sea

During the cruise, pore-water and solid-phase samples will be collected by means of multiple corer (MUC) and gravity corer (GC) deployments in the Cumberland Bay Fjord, the King Haakon Bay as well as in the associated Troughs 5 and 9. In addition, we plan to collect pore-water and solid-phase samples in shallow waters of the fjords using a hand-held gravity corer on-board a Zodiac as well as a field sampling campaign at the beach of the Cumberland Bay and the King Haakon Bay.

After arrival of the cores on deck of *Polarstern*, the MUC cores will be cut into 1 to 2 cm thick slices, which are placed into 50 ml centrifuge tubes. At each station, an additional MUC core will be used for ex-situ oxygen measurements. The gravity cores will be cut into 1 m segments and split into work and archive halves. The samples/sediment cores will subsequently be transferred into a refrigerated laboratory container (4° C).

Pore water will be extracted using rhizons with an average pore size of 0.15 µm (Seeberg-Elverfeldt et al., 2005) either from sealed centrifuge tubes in the case of MUC samples or directly from GC working halves. For gravity cores, pore-water samples will be taken in intervals of 20 to 30 cm. Solid-phase samples will be collected with 10 ml cut-off syringes at the pore-water sampling intervals.

On-board pore-water analyses include the determination of alkalinity, dissolved Fe, nitrate, nitrite, ammonium, phosphate and silica, as well as chloride concentrations. In addition, pore-water aliquots will be preserved and adequately stored for the shore-based analyses of sulfate, chloride, hydrogen sulfide, dissolved inorganic carbon, major and minor cation concentrations, as well as the stable isotopic composition of dissolved Fe. Redox potential and pH will be determined on-board parallel to the pore-water and sediment sampling intervals using punch-in electrodes. The solid-phase samples will be stored frozen (–20° C) under anoxic conditions for shore-based inorganic geochemical, mineralogical and sedimentological analyses.

Expected results

The high-resolution multidisciplinary approach including the investigation of the water column and the sediment in combination with the field sampling campaign provides the unique opportunity to gain a better understanding of the sources and transport mechanisms of Fe, nutrients and trace metals that are not considered (e) or relatively unexplored (f) so far. Identifying and quantifying the (main) sources and transport pathways of the interstitial constituents into the shelf water of South Georgia will improve the assessment of the region's sensitivity under changing climate conditions.

Data management

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

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

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5. IMPACTS OF VARIOUS IRON SOURCES ON BIOAVAILABILITY OF IRON AND PLANKTON COMMUNITY COMPOSITION

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Grant-No. AWI_PS133/2_04

Objectives

Extensive open water phytoplankton blooms occur along the flow of the southern Antarctic Circumpolar Current downstream of the island South Georgia. The sources and magnitude of iron (Fe) inputs fueling productivity in these land-remote areas are poorly known. These substantial algal blooms require significant Fe inputs, but the actual Fe supply mechanisms and their relative importance for primary production and biogeochemical processes along the flow of the southern Antarctic Circumpolar Current (S-ACC) remain largely unconstrained. Current hypotheses for the main Fe sources fuelling the large blooms along the S-ACC downstream of South Georgia are: i) Entrainment into the mixed layer of Fe-enriched deep waters originating around South Georgia through winter mixing and deep sources east of the large S-ACC bloom. ii) External sources such as atmospheric dust and icebergs and iii) lateral advection and recycling of particle associated Fe (living matter and detritus), potentially mediated by zooplankton feeding activity. Currently, we lack observational data on the relative importance of each of these different Fe supply mechanisms. We, therefore, first aim to quantify the main Fe pools in several surveys across the main flow of the S-ACC from the potential source in South Georgia (38°W) to the eastern boundary of the high productivity plume around 0°E. The second important aim will be to investigate how bioavailable the Fe in different pools is to SO phytoplankton. In addition, the presence/prevalence of phytotoxins in the Fe-induced phytoplankton blooms will, for the first time, be investigated.

As part of the overall goal of expedition PS133 “Island Impact” we aim to:

- characterize the Fe distribution patterns, stocks and origin along the water column
- measure primary and bacterial production rates in the euphotic zone
- determine pico- and nanoplankton composition at 20 m depth
- assess Fe uptake rates, trace metal quotas, photophysiological status and *in-situ* diatom species-specific growth rate at 20 m depth
- assess the distribution of several key phycotoxins
- determine the Fe bioavailability of different Fe sources (deep water, hydrothermal influenced seawater, grazing products from copepods) through 24 h incubation experiments

Work at sea

In order to characterize the vertical profiles of trace metal chemistry (dissolved and particulate Fe, dissolved and particulate Fe isotopes, Fe chemical speciation, concentrations of ligands and humic-acid like substances) seawater will be sampled at <50 stations on the shelf, and in King Haakon Bay and Cumberland Bay, South Georgia Island. In addition to the vertical profiles, at each station, we will also determine primary- and bacterial production rates, Fe uptake rates, trace metal quotas, photophysiological status and *in-situ* diatom species-specific growth rate from 20 m depth. At <6 stations, seawater will be sampled with a TM clean Teflon pump and used to conduct experiments investigating the impact of different Fe sources on their bioavailability to phytoplankton. In addition, dilution series experiments will look at the role of microzooplankton grazing on carbon cycling.

More specifically:

1. At <50 stations seawater will be collected trace metal clean with the AWI's new, state of the art, trace metal clean sampling infrastructure including a Teflon CTD equipped with OTE bottles (12 L/bottle capacity) and winch. At these stations (0 m – bottom, 16 depths), ultra-clean CTD casts will be used to sample for concentrations of dissolved trace metals (Fe, Mn, Zn, Co and Cu), particulate Fe, ligands, humic acid-like substances and Fe chemical speciation from each depth. From 8 depths, we will sample for dissolved and particulate Fe isotopes. Samples for colloidal Fe will also be taken from 20 m depth.

2. In addition, at the 50 sampling stations, we will collect seawater from 20 depth to determine size fractionated (0.2–2, 2–20 and > 20 µm) primary- and bacterial production rates using ^{14}C-bicarbonate and ^{3}H-leucine, respectively. Also, uptake rates of Fe and B_{12} will be measured using ^{55}Fe and ^{57}Co-B_{12}. In addition,, samples will be taken to determine the intracellular content of the trace metals (Fe, Mn, Zn, Co and Cu) of phytoplankton. Using a Fast repetition rate fluorometer onboard, we will also assess the photophysiological status of the sampled phytoplankton community at 20 m depth. In addition, *in-situ* diatom species-specific growth rate will be estimated using the stain PDMPO.

3. At 2 stations, seawater will be pumped on board with the help of a Teflon membrane pump. For this, a LDPE Hose will be lowered to 20 m and ~1,500 L seawater will be pumped directly into a trace metal clean container where bottles and tanks will be filled for the bioavailability experiments. Treatments will include the addition of different Fe sources including deep water, hydrothermally influenced seawater (in cooperation with S. Henkel), and fecal pellets from two different copepod species (cooperation with M. Iverson).

At 6 stations a dilution series will be set up by mixing whole seawater with 0.2 µm filtered seawater at 100 %, 75 %, 50 % and 30 %. All bottles will be incubated in climate-controlled laboratories at ambient light and temperature conditions and for 24–72 hs depending on the experiment.

Expected results

The expected data set will characterize the trace metal distribution and biogeochemistry in the open waters downstream of South Georgia. Our study will provide vertical profiles of TMs in this biologically active area and elucidate their vertical distribution and possible sources. Rate measurements of primary and secondary production, coupled to uptake and recycling rates of TMs and vitamins will shed light on the cycling and dynamics between these essential trace nutrients and the pelagic plankton community. In addition, targeted experiments, in which natural plankton communities are exposed to various TM sources including deep water, hydrothermally influenced seawater (in cooperation with S. Henkel), and fecal pellets from two different copepod species (cooperation with M. Iverson) will determine their Fe bioavailability to phytoplankton. Lastly, samples of phytotoxins collected will, for the first time, explore the extent to which potentially harmful or ecosystem disruptive algae are present and if Fe plays a role in their ecology.

Data management

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

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

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6. IRON ISOTOPES IN THE WATER COLUMN

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Objectives

Our main goal is to gain a better understanding of coastal and shelf sources and processes that deliver essential nutrients, especially Fe, to the SO and thereby stimulate phytoplankton growth. In high nutrient low chlorophyll (HNLC) regions like the SO, the input of the limiting nutrient (usually Fe) can substantially enhance the biological pump, but the effects cannot be well assessed by models since data are scarce and our understanding of Fe transport pathways in remote coastal and shelf areas is very limited. Not all of the potential Fe sources are expected to contribute continuously or to be equally sensitive with respect to climate change. The objective of the Iron Isotopes Water Column team is to identify and quantify Fe sources in fjords of South Georgia and to assess in which form and by which processes, e.g. precipitation of fresh Fe oxides and export in nepheloid layers, Fe is laterally transported towards the open ocean.

Work at sea

Early diagenetic iron release from SG fjord and trough sediments will be investigated by a combination of sediment and pore water sampling (see chapter 4) with trace metal sampling of the water column using the recently at AWI established Clean Rosette-CTD system. Increased Fe concentrations in bottom water with a negative Fe isotope signature as typical for Fe liberated from sediments by dissimilatory iron reduction (Staubwasser et al., 2013; Henkel et al., 2018), a microbially mediated process, and Fe flux calculations based on pore water data will enable us to evaluate the Fe release by benthic processes in two model areas of South Georgia: the Cumberland Bay Fjord and the King Haakon Bay. Active methane seepage – i.e. gas bubble ebullition – was shown to be abundant in the fjords and troughs of South Georgia – including Cumberland Bay Fjord (Römer et al., 2014; Geprägs et al., 2016) and King Haakon Bay (Bohrmann et al., 2017) and is hypothesized to locally increase the benthic Fe fluxes. The selection of sampling sites will depend on sedimentology and the circulation patterns in the fjords, but also on the occurrence of active methane seeps. Those data will be gained by other groups participating in expedition PS133/2.

Other important sources investigated in this study will be (submarine) groundwater as well as (sub)glacial meltwater runoff to be detected during PS133/2 using temperature and salinity measurements (CTD deployments), $\delta^{18}O$ signatures, and its flux approximated via radon (Rn) and radium (Ra) analyses (chapters 11 and 15).

The respective complementary Fe and Fe isotope samples will be selected and processed to specifically determine Fe concentrations and stable Fe isotope signatures (“endmembers”) in those sedimentary and runoff sources. The characterization of $\delta^{56}Fe$ endmembers in (sub)polar regions is generally important, because glacial margin systems appear to impart a significantly light composition and high abundance of dissolved Fe into coastal waters (Henkel et al., 2018), but $\delta^{56}Fe$ endmembers for different types of sediments, environmental conditions, and biogeochemical processes are not yet well enough constrained.

An important aspect to be investigated is equilibrium and/or kinetic isotope exchange between dissolved Fe and the reactive surfaces of particulate Fe phases. Here, an on-board experiment series accompanied by on-shore laboratory experiments will be conducted. A quantitative understanding and correction of these potentially continuous in-process exchanges on transport from the shelf to the open ocean environment are necessary to trace Fe sources by isotopic fingerprinting.

As part of the overall goal of PS133/2 we aim to:

- characterize the Fe distribution patterns, stocks and origin along the water column;
- determine Fe isotope fractionation between dissolved and suspended Fe to identify potential mineral Fe sources and internal Fe cycling.

From the surroundings of South Georgia and in each of the two fjords, a total of 11 stations will be sampled for trace metals and Fe isotopes using a clean CTD system. The depth range will be surface to shelf bottom or – in the troughs – surface to 1,000 m. For Fe isotope studies, we will collect 10 L volumes of seawater. Each sample will be filtered through individual 0.2 or 0.45 µm filter capsules. The filter capsules will be stored and leached for reactive Fe phases after the cruise. In addition to these 11 clean CTD deployments, shallow sites (inaccessible for *Polarstern*) will be sampled using separate sampling bottles deployed from a zodiac. Furthermore, groundwater discharges at the beaches are planned to be sampled. Finally, experimental time series of isotope exchange between dissolved and particulate iron will be conducted using a ^{54}Fe enriched spike and the three-isotope method to determine exchange fractionation factors.

Expected results

The expected data set will characterize the trace metal distribution and biogeochemistry in two model areas of South Georgia, the Cumberland Bay Fjord and the King Haakon Fjord. Our study will provide vertical profiles of trace metals and elucidate their vertical distribution and possible sources.

Data management

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

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7. METHANE MEASUREMENTS – SEDIMENT, WATER COLUMN AND ATMOSPHERE

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not on board: Evelyn Workman[2] [2]UK.BAS

Grant-No. AWI_PS133/2_06

Objectives

Methane is a potent greenhouse gas, which has a 28-36 times higher global warming potential than carbon dioxide on a 100-year timescale (Myhre et al., 2013). The concentration of methane in the atmosphere has been increased since the industrial revolution and presently concentrations are approximately 2.6 times higher than pre-industrial level (Saunois et al., 2020). Consequently, reducing methane emissions and subsequently atmospheric methane concentrations are an important step to keep the "Paris Agreement" of 1.5 °C of global heating (Cain et al., 2022). Therefore, global sources and sinks of methane need to be explored.

The oceanic contribution to the global atmospheric methane budget is not yet fully investigated (Saunois et al., 2020). Oceanic methane sources include production by phytoplankton and methane seeps from seabed. Due to low available datasets global ocean emissions remain highly uncertain, especially in polar regions. A recent investigation estimated methane emissions in the Southern Ocean based on underway measurements from cold temperate to Antarctic areas (Bui et al., 2018). Several studies (Römer et al., 2014; Del Valle et al., 2017; Spain et al., 2020; Thurber et al., 2020) reported the first observations of methane seepage from shallow nearshore waters in Antarctica and sub-Antarctic islands. Methane seeps are abundant within the fjords and continental margin of South Geogia.

The extent of increased methane concentrations within the water column and its potential consumption will be assessed by discrete water sampling and by high spatial resolution measurements with an UWMS (Underwater mass spectrometer). The air sampling during expedition PS133/2 will be complementary to the sediment and watercolumn sampling and will detect methane concentrations from locations with confirmed methane seabed seepage.

With this combined data set, we will quantify the contribution of the Southern Ocean and its methane seeps to local carbon budgets in response to regional climate change, and interaction with the adjacent ocean. The transport, reaction pathways and fluxes between sediment, coastal sea, and atmosphere will be quantified.

Work at sea

Dissolved methane concentrations:

Dissolved methane concentrations will be obtained by water sampling with the rosette/CTD system at several depths inside the fjords and at reference stations outside the fjords. Samples will be filled into glass vials and analysed via head space method (Magen et al., 2014).

The *in-situ* concentration of methane will be mapped by a new designed UWMS in high temporal and spatial resolution (Gentz et al., 2014). The UWMS is able to analyse the gascomposition in about one second, which results in a high-resolution mapping of methane around gas seeps as well as in the fjord habitats.

Methane oxidation rates:

To determine the biological sink of dissolved methane i.e., the methane oxidation rate (MOX), water samples will be spiked with radiolabelled methane. After incubation at near *in-situ* conditions the produced radiolabelled water will be determined and the MOX calculated (Bussmann et al., 2015). In addition, some experiments on the influence of methane concentration and of nutrient limitation on MOX are planned. Information on the methanotrophic bacterial population will be obtained by filtering water and subsequent molecular analysis of the filters.

LosGatos greenhouse gas analyser work:

Ambient methane concentrations will be measured continuously by an LosGatos greenhouse gas analyser (GGA). The GGA will be calibrated regularly with standard gases. If possible, in collaboration with the water column measurements, additional sea-air methane fluxes will be measured, in line with previous methods used by M. Yang and T. Bell for comparability (Yang et al., 2019). With this dataset and additional information on wind speed and dissolved methane concentrations the methane flux can be calculated at high spatial resolution.

Air sampling by hand-held pump:

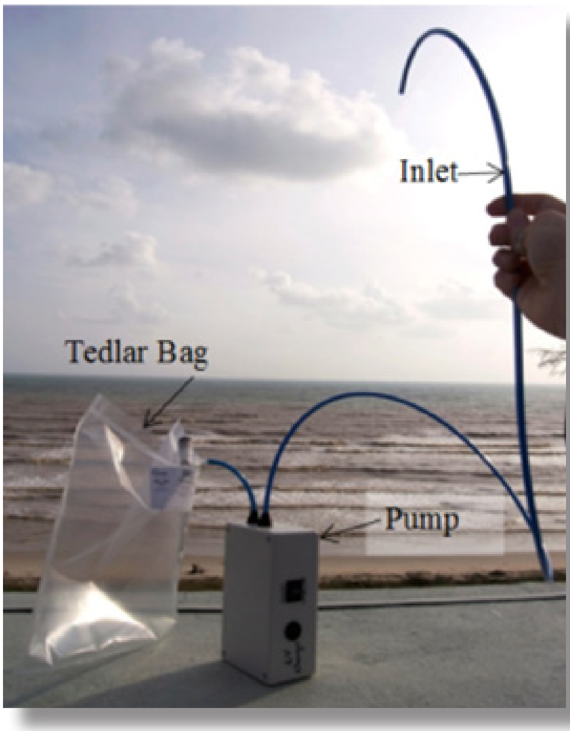

Fig. 9.1: Small battery powered pump and tedlar bag used to collect air samples

On board, air samples will be collected in tedlar bags using a small battery pump at regular, twice daily intervals, before dawn and mid-day in international waters and around South Georgia (Fig. 7.1). The tedlar bags will be stored within the temperature range of +4 to +10 °C. The filled tedlar bags will be transported back to the UK as soon as possible for isotopic analysis of the methane at the greenhouse gas laboratory at Royal Holloway University of London (France et al., 2022).

Sediment sampling:

Marine sediments will be taken by gravitiy coring to sample gas hydrates. These hydrates will be unfrozen on board, stored as gas in glass vials and analysed at the MICADAS-facility at AWI-Bremerhaven to determine the radiocarbon age of the gas hydrates. A new method for that application is currently established.

Expected results

The combination of high-resolution water column and atmospheric data, together with the information on the biological pathway of methane will allow us to budget the methane flux from the water column into the atmosphere, with a special focus on possible hot spots within the fjords.

Analysing the air close to the ocean's surface above the Southern Ocean will also help to determine if there are regional sinks or sources of methane in the observed area. Studying the shelf of South Georgia in comparison to the High Seas area will determine how much influence sub-Antarctic and Antarctic land masses have on the global methane budget.

Additionally, the age determination of the gas hydrates could led to new insights regarding the methane sources.

Data management

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

Atmospheric methane isotopic data will be submitted to, archived, published and disseminated by the UK Polar Data Centre (PDC) hosted at the British Antarctic Survey.

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Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. http://dx.doi.org/10.17815/jlsrf-3-163.

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8. NATURAL RADIONUCLIDES

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Outline

The timescales of offshore transport in the ocean can be studied with natural radionuclides, in particular with radium isotopes. These have their source in sediments, and following their release into the water, they decay with a specific half-life. This can be used to estimate fluxes from ground and pore waters into the ocean, and to follow their distribution. Here, we combine the information from short-lived radium isotopes ^{224}Ra and ^{223}Ra (the latter possibly expected to be very low) with the long-lived radium isotopes ^{226}Ra and ^{228}Ra. In addition, we study ^{222}Rn/^{226}Ra disequilibria for a tentative assessment of gas fluxes. We link the information from radium to information from particle composition in order to assign sources, identify transport mechanisms and reveal chemical properties that control trace element budgets of the Southern Ocean.

Objectives

Our objectives are

1. to measure radium/trace element ratios on potential groundwater sources to the ocean, together with ^{222}Rn
2. to determine the inventory of several radium isotopes and ^{222}Rn (at least ^{224}Ra and ^{226}Ra) in one or more fjords
3. to measure ^{226}Ra and (where possible) the ^{228}Th/^{228}Ra ratio in intermediate nepheloid layers, if observed
4. to sample particles transported offshore and measure their elemental composition, in combination with the radium signature of the surrounding water

Work at sea

Our work at sea is split in three aspects:

1. Sampling of large-volume samples (80 to 120 L), absorbed onto manganese coated fiber, for short-lived radium from the standard CTD rosette (Jones). In combination, 2 L samples will be taken for ^{226}Ra
2. Sampling of pore waters and groundwater seepages for ^{224}Ra and ^{226}Ra (Jones/Geibert), and ^{222}Rn (Geibert/Köhler)
3. Collection of filter samples for elemental analyses and Mn-coated absorbers for radium isotopes with *in-situ* pumps offshore, following other transects (Köhler/Geibert)

Sampling devices:

1. Submersible pumps (*in-situ* pumps), one of which (“Seafeather10k”) delivers CTD-sensor data
2. Standard-CTD
3. Rhizons for pore water sampling

On board detection systems:

1. Radium delayed coincidence counter (RaDeCC) for ^{224}Ra, ^{223}Ra and indirectly ^{228}Th and ^{228}Ra/^{226}Ra ratios
2. Triathler (manufactured by Hidex), liquid scintillation counting system for ^{222}Rn and indirectly ^{226}Ra in discrete samples
3. Rad-7 (manufactured by Durridge Inc.), a specific ^{222}Rn gas counter that can be used for continuous transects

On board processing:

1. “Clean Cut” laser cutting device for filters
2. Gravitative filtration of large water samples (80 to 120 L) over manganese coated fiber

Planned post-cruise analyses:

1. Precise ^{226}Ra on small volume (< 2L) sea water samples with ICP-MS
2. Ratios of ^{228}Ra/^{226}Ra in leached Mn-fiber by gamma spectrometry
3. Electron microscopy on filter aliquots
4. Bulk element analyses on filter samples

Expected results

Previous results (Annett et al. in prep.) have shown that in the North Atlantic and adjacent shelf seas, intermediate nepheloid layers, as traced with radium, can be an important source of trace metals to the ocean. They seem to be associated with the depth of a shelf break or other structures that cause enhanced turbulence. We hope to replicate a part of these findings in the Southern Ocean, an environment much lower in both radium and limiting micronutrients. On offshore transects, we will follow the plume of dissolved and particulate elements with filters and absorbers. The filters will be cut in aliquots for different working groups by means of a clean laser cutting device (AWI “CleanCut” from innovation fonds). On these filters, we expect to see a combination of biogenic particles, lithogenic particles, and authigenic mineral phases, which are of particular interest for trace element cycling due to their reactivity. These will be characterised by scanning electron microscopy with energy-dispersive X-Ray fluorescence analysis (SEM-EDX) element distribution maps for a semi-quantitative characterisation of minerals, together with quantitative measurements of particulate trace elements on full digestions of the material.

With the short-lived radium as measured with the Radium Delayed Coincidence Counter (Moore and Arnold, 1996), we expect to be able to construct a radium inventory for at least one fjord. In combination with radium/trace element ratios from possible sources and the half-life of the radionuclide(s), this will yield an integrated flux of trace elements to the fjords. When brought together with trace element distributions -at least iron, manganese and barium- in the fjords, this view will give an assessment of the removal that takes place in nearshore environments immediately after their release.

Measurements of radon- in pore water complement the measurements in pore waters. The disequilibrium of ^{222}Rn and ^{226}Ra in surface sediment is a measure of gaseous release for sediments. We expect to see a depletion of radon near the sediment surface; the short half-life of 3.8 days reflects only short-term processes. As a noble gas, radon reflects purely physical aspects of gas release from sediments.

With the newly developed method of mass-spectrometric ^{226}Ra measurements on small-volume seawater samples (Vieira et al., 2021), we aim to resolve the small ^{226}Ra signature that comes off the island to trace the plume/intermediate nepheloid layer by means of high measurement precision. In combination with the trace element/^{226}Ra ratios, this may help in constraining the role of subantarctic islands for Southern Ocean trace element budgets in the future.

Data management

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

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9. MACRO- AND MEGABENTHIC METHANE SEEP FAUNA

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Objectives

Methane is confirmed as one of the potent climate change gases with a global warming potential higher than carbon dioxide (Wadham et al., 2012). Marine methane in the Southern Ocean (SO) is estimated to comprise about a quarter of the Earth's marine methane (Michaud et al., 2017). In recent years, first records of methane seepages from the seafloor and raised methane concentrations in the overlying water column have been reported from sub-Antarctic islands and the Antarctic shelf (Römer et al., 2014; Geprägs et al., 2016; de Valle et al., 2017; Spain et al., 2019). Research to date has focussed on the Arctic, with investigations on the origins, amounts and effects on the ecosystem of methane emissions (Åström et al., 2018, 2020), but there has been minimal research in the SO. More specifically, significant gaps exist in relation to the responses of the SO benthic faunal communities to methane and their role in whether seepage areas are sources or sinks.

To date research on methane as a climate change gas with global warming potential has focussed on terrestrial methane (Wadham et al., 2012; Michaud et al., 2017). Marine methane in the SO could play an important role in a) climate change and b) may also impact SO biodiversity and ecosystem function as a result of the increased marine methane seepage caused by warming of the Antarctic continental shelf.

Evidence of methane seepage has come from a number of sources including the detection of raised methane in sediments at the eastern Antarctic Peninsula, gas flares on the Kerguelen Plateau, gas hydrate in the South Georgia shelf and methane seepage including bacterial mats in nearshore, shallow waters of the Ross Sea (Bohrmann et al., 2017; del Valle et al., 2017; Spain et al., 2019; Thurber et al., 2020). However, to date no living chemosynthetic mega- or macrofauna, generally associated with deep-sea methane seepage have been reported from the SO seepage sites.

The benthic fauna of South Georgia is highly diverse (1,445 species; Hogg et al., 2011), and marked by a cumulative dominance of endemic and range-edge species, as well as by a high number of recorded rare species. Before the discovery of methane seepage by Römer et al. (2014) no confirmed cold seep activities were known from the continental shelf of South Georgia and to date no chemosynthetic benthic fauna has been reported. Bell et al. (2016) studied the composition and trophic structure of macrofauna from southwestern troughs, characterized by elevated methane levels in the sediments, and reported on very limited contribution of methane–derived carbon to the food web. Linse and Hogg during cruise M134 (Bohrmann et al., 2017) noted higher macrofaunal abundances in samples from the methane-elevated sediments in the southwestern troughs of South Georgia than in samples from seepage sites in the northern ones, but neither community composition nor trophic interactions have been fully investigated across the full range of methane seepage conditions. In the eastern Antarctic Peninsula, benthic fauna from carbon-enriched sites suggests that these are from opportunistic taxonomic groups, which are often found in association with methane seepage but are not dependent on it (Bell et al., 2016, 2017). This pattern has been observed in other areas of the ocean where methane seepage occurs but lacks charismatic megafauna which are often observed in methane seep habitats (Åström et al. 2018, 2020). This suggests that the role of methane sustaining marine benthic food webs is being underestimated, and that identifying seepage locations may be too reliant on larger, visual cues.

This project will investigate the community composition, functional traits and trophodynamics of benthic fauna from methane seepage influenced habitats at South Georgia and compare it to benthic fauna from carbon enriched habitats in the SO, which are hypothesised or known to be influenced by methane seepage. The research will use a combination of the biogeochemical techniques (e.g. stable isotope and lipid analyses) to elucidate the food source of benthic fauna and establish the degree of dependence on methane sources; morphological analysis to identify species and establish potential functional traits; and statistical analysis to understand the response of the benthic communities to varying sediment geochemical conditions. There will be an emphasis on understanding the role of bivalves as potential indicator species of hydrocarbon- and carbon-enriched habitats in the SO, which will lead to a biogeographical analysis and the identification of potential future exploration sites.

The objectives of the benthic methane seep fauna project are:

- Study species richness, abundance, community composition, functional traits and small-scale distributions of macro- and megabenthic fauna in methane influenced habitats and link these to environmental parameters. Species distributions will be assessed vertically in the sediment and at different methane seepage sites – multicorer and Rauschert Dredge collections;
- Elucidate the trophic role of macrobenthic fauna in local South Georgia food web and their reliance on methane seep associated food sources – multicorer and Rauschert Dregde collections, stable isotope analyses of soft tissues and bivalve shells;
- Compare South Georgia methane seepage influenced habitat community composition with other SO and shallow water methane seep communities – literature records, multicorer collections.

Work at sea

We will work closely with the marine sedimentologists, microbiologists and geochemists on the methane influence habitat on the shelf of South Georgia, especially in the Cumberland Bay Fjord and the King Haakon Bay and their associated troughs 5 and 9 as model areas. We will co-use tubes from the multicorer (MUC) deployments for quantitative macrofauna assessments and perform Rauschert Dregde deployments for qualitative megafauna collections.

Multicorer work

On arrival on deck, all tubes of the MUC will be photographed to record sediment height, layering and colour. After tubes will be taken for analyses of pore water, methane, solid phase, microbiology, Fe isotope and magnetic analyses, the remaining tubes will be available for macrofauna analyses. Each tube will be sliced at 0 – 2 cm and 2 – 5 cm layers using a core extruder, resulting in at least two individual samples per tube. Mobile, larger macrofauna visible on the top of tubes will be sampled separately. Samples for macrofauna analysis will be sieved on deck through a 300 µm sieve in ambient sea water (temperature of 2–5° C), depending on time live photographed and fixed in 96% ethanol or individually frozen. After at least 48 h ethanol fixation at –20° C, the benthic specimens will be sorted to different taxonomic levels, from order to morphospecies level, under a Meiji stereomicroscope, counted and transferred to appropriate curatorial vials. Selected specimens and morphospecies will be imaged using an AmScope MU1803 camera.

As the number of tubes and potentially tube diameters per station will vary, abundance data will be normalized to m^2 for quantitative analyses following the general practice in the analysis of deep-sea macrofauna collected by multicorer (Glover et al., 2008; Ingels et al., 2012).

Rauschert Dredge work

The Rauschert Dredge will be deployed on the shelf and in the vicinity of methane seepage to collect megafaunal specimens. On arrival on deck, the catch will be cleaned by sieving under ambient sea water, sorted to morphospecies, photographed and fixed as full specimens or tissue samples in ethanol or frozen for later morphological and food web analyses.

Expected results

At sea, MUC macrofauna will sorted to higher taxon and morphospecies level, counted for abundance assessment, and the preliminary community homogeneity assessed. In cooperation with the sediment biogeochemists, we plan to analyse community patterns against theiron board analysed parameters, e.g. alkalinity, Fe^{2+}, Mn^{2+}, NO_3, NO_2, PO_4, SO_4, CH_4, CO_2, H_2. Rauschert Dredge samples will be catalogued for their further analyses.

The results of our planned stable isotope and food web analyses on benthic fauna will allow us to elucidate longer-term dietary signals (including those characteristic of pelagic copepods with marker fatty acids) will allow to estimate what role methane seepage plays in the South Georgia food web and carbon draw down.

Data management

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

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

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

After identification, macro- and megabenthic biodiversity data will be submitted to, archived, published and disseminated by the UK Polar Data Centre (PDC) hosted at the British Antarctic Survey. Physical collected specimens, when not destroyed for analyses, will be stored at the British Antarctic Survey until analyses publication and then archived in a natural history museum for international access.

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10. BIOGEOCHEMISTRY AND MICROBIOLOGY

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Grant-No. AWI_PS133/2_09

Outline

Objectives

The biogeochemistry and microbiology group has two main objectives: (1) To investigate microbial processes with a focus on iron and sulphur cycling in order to broaden our understanding on key anaerobic respiratory processes. In detail, we will investigate how they are controlled by the availability of electron acceptors, i.e. iron and sulfate; whichs availability is also impacted by glacial input in sediments around South Georgia (SG). (2) To investigate the identity of sedimentary ancient eurcaryotic DNA (sedaDNA) to draw conclusions on changes in biodiversity (of algae, animals and plants) over longer timescales under changing climate conditions.

For our first objective, we could show previously that the availability of electron acceptors (i.e. iron oxides and sulfate) has a strong impact on microbial communities in sediments from SG (Wunder et al., 2021). Intriguingly, known sulfate reducers appeared to be abundant in surface sediment, yet iron reduction was the dominant anaerobic respiratory process. To build up on these results we plan to (a) study more sediment sites, (b) determine rates of sulfate reduction (SRR) and anaerobic oxidation of methane (AOM, either coupled to sulfate reduction or the reduction of iron oxides), and (c) identify electron donors that might fuel sulfate reduction *in-situ* using RNA stable isotope probing (SIP). Additionally, we plan to investigate the potential for the microbial degradation of the frequent algal sulfated sugar polymer fucoidan as well as lignin and lignin model compounds (vanillin).

By applying kinetic iron extractions we could show that in sediments of Svalbard fjords benthic cycling of iron is important for transforming iron from glacial sources (Laufer-Meiser et al., 2021). Also within our first objective, we will investigate the reactivity of iron minerals towards microbial reduction in samples from glacial sources, the water column and sediment by kinetic iron extractions in order to see if we can find similar patterns as in Svalbrard fjords. Moreover, we will study microorganisms involved in iron cycling (by cultivation dependent and cultivation-independent methods) within the sediment samples.

For our second objective, analysis of sedaDNA will be done to identify the past taxonomic composition and turnover of various organisms throughout the sediment record. This can be discovered by either target-specific approaches like metabarcoding (Liu et al., 2021; Stoof-Leichsenring et al., 2022; Zimmermann et al., 2020, 2021) or total sedaDNA shotgun sequencing (Courtin et al., 2022; Schulte et al., 2021). This helps to understand biodiversity change under past natural climate and related environmental conditions as well as under intensified human impact during the recent past.

Work at sea

Our group will be involved in collecting sediment samples from MUC and gravity cores. Once sediment samples have been collected, radioactive tracer experiments will be set up and stable isotope probing incubations for RNA-SIP will be started. SRR will be measured in surface sediments using ^{35}S-sulfate (Jørgensen, 1978; Røy et al., 2014). After incubation at *in-situ* temperature, samples for SRR measruements will be fixed in zinc acetate and stored and shipped frozen at –20° C. For quantification of SRR, the cold-chromium distillation method (Kallmeyer et al., 2004) will be applied in the home laboratory in Kiel. Potential rates of AOM coupled to sulfate reduction will be measured in slurries using ^{14}C-methane and ^{35}S-sulfate (new adaptation from Treude et al., 2003; Røy et al., 2014). RNA-SIP (Yin et al., 2019) experiments will be set-up with ^{13}C-labeled ethanol and sulfate and later processed in the home laboratory in Bremen. During the incubation the development of different geochemical parameters will be tracked (dissolved Fe(II), sulfide) and samples for later sulfate measurements will be stored.

Samples for measuring the reactivitiy of Fe-minerals with kinetic extractions will be taken from subcores under anoxic conditions. Furthermore, samples of praticles from glacial sources (e.g. from rivers or lakes), as well as seawater will be taken. Samples will be immediately frozen and analysed at the home laboratory in Kiel. On selected subcores, MPN (most probable number) incubations as described in Laufer et al., (2016) will be done. Samples for DNA extraction and community analysis will be taken from positive samples and from the original sediment samples.

After the retrieval of sediment cores subsamples for sedaDNA analytics will be taken immediately using sterile subsampling devices and will be frozen at –20° C. Further analytical steps will be conducted in the clean paleogenetic laboratories at AWI in Potsdam, Germany (https://www.awi.de/en/science/geosciences/polar-terrestrial-environmental-systems/labs-and-methods/paleogenetic-lab.html)."

Expected results

Expected results include SRR from surface sediments, following transects, preferably in Cumberland Bay and King Haakon Fjord. Further, SRR in surface sediments of Drygalski Fjord, Royal Trough and Church Trough will be determined. Additional incubation experiments with sediments from Royal Trough will give insights into the SRR, coupled to rates of AOM. SIP experiments will give insights into active sulfate reducing microorganisms, which metabolize the simple alcohol ethanol.

Results will include information on the amount and reactivity of particulate iron in material from glacial sources, seawater and sediments within transects preferably in Cumberland Bay and King Haakon Fjord. Results of MPN incubations and sequencing will provide insights into the microbial community potentially involved in iron cycling within these sediments.

Applying the sedaDNA approach we expect to characterize changes of the local ecosystem and its environmental drivers in the past mainly covering centennial-millennial timescales depending on the resolution of sediment cores. As an example, previous sedaDNA analytics performed in our paleogenetic laboratories at AWI deciphered past diatom composition and its relation to sea-ice and climate dynamics in the North Pacific over the last 20 ka (Zimmermann et al., 2021) and in the Fram Strait (30 ka) (Zimmermann et al., 2020)."

Data management

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

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ). Additionally, DNA data and bioinformatic scripts for data analyses will be made publicly available on the data repository Dryad (https://datadryad.org). Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data."

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

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11. PHYSICAL OCEANOGRAPHY

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Objectives

The Southern Ocean contains so-called high nutrient low chlorophyll areas in which macronutrients are abundant, but micronutrients (primarily iron) limit primary production (the growth of phytoplankton). The work on Island Impact leg 1 (PS133/1) preceding expedition PS133/2 will map out some of these areas and in particular the temperature/salinity characteristics of the water masses that are or are not iron limited. Tracers such as iron are either passively advected with currents and mixed with water masses or they are modified by biological processes (primary production, remineralization). Coastal and shelf sea processes (e.g. around the archipelago of South Georgia) form new water masses with distinct temperature/salinity characteristics and they also introduce iron originating from land to the water column. Therefore, the identification of water masses on the shelf of South Georgia (and their origins) together with their iron concentrations allows for the computation of their contribution to iron concentrations across the Atlantic sector of the Southern Ocean.

Work at sea

At a selected number of stations, we will operate the AWI Oceanography Section's CTD rosette for the TS characteristics of water masses and the collection of water samples. The rosette also contains a lowered ADCP (upward and downward looking Acoustic Doppler Current Meters). In addition, we will operate the ship's vessel mounted ADCP. The combination of these two types of direct current measurements will help to support the interpretation if and how the coastal and shelf sea water masses leave the shelf, thereby transporting their tracers to the open Southern Ocean.

At all times, also underway measurements with the thermosalinograph (for temperature and salinity) will be collected.

Finally, we will operate the ultra clean CTD which allows for the collection of iron samples along with the same kind of high quality CTD data (originating also from a Seabird 911+ CTD) as on the non-ultra clean rosette.

Expected results

For all of the occupied stations, preliminary CTD cast data (the quality of the data will be improved later through post-cruise calibration and processing) will be available during the cruise for interpretation of the encountered water masses and their current direction.

Data management

The raw CTD data from the two rosettes and the velocity data from the two ADCP systems will be made available through the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the cruise. The finally processed CTD and velocity data will also be made available through PANGAEA when processing has been completed. By default, the CC-BY license will be applied.

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12. MARINE PARTICLES, SINKING FLUXES AND NUTRIENT CYCLING IN SURFACE SEDIMENTS

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Grant-No. AWI_PS133/2_11

12.1 Marine Particles and sinking Fluxes

Objectives

Our main objectives are to understand the dynamics and export of marine particles in the different (probably iron-dependent) productivity regimes along the cruise track of PS133/2 "Island Impact" study. During the voyage we will focus on

- Measuring particle (plankton and aggregates) size-distribution, abundance and composition in the water column.
- Measuring export fluxes below the upper mixed layer depth and the permanent thermocline and determine the composition and characteristics of the sinking matter.
- Determine processes that influence particle dynamics and sinking fluxes.
- Determine the impact that particle formation, recycling and export has on nutrient stoichiometry.

Work at sea

Particle characteristics (size, shape, type and origin) will be determined through the deployment of a UVP5 underwater video profiling system attached to the CTD-rosette sampler. This will be complemented at the longer "process study" stations with coupled CTD and underwater camera systems to allow quantification of the whole size-spectrum including the larger macrozooplankton and aggregates (ROSINA and JellyCam).

Where possible, export fluxes will be below the mixed layer (when time and depth allow ~100, ~300 and ~400 m) using a free drifting array with three sediment trap stations (KC, Denmark) consisting of four cylindrical sinking matter collectors each (Fig. 12.1). Material from three collectors at each depth level will be used for biogeochemical analyses of particulate organic matter composition, and molecular microscopic analysis of planktonic organisms. The fourth collector at each depth will be filled with a viscous gel to preserve size and shape of sinking particles (Fig. 12.1). These will be digitally analysed on board.

Furthermore, a large volume sampler, the Marine Snow Catchers (MSC), will be used to collected *in situ* formed marine snow and other particles. The MSC consists of a 100 L cylindrical water sampler with a particle collection tray at the bottom and will be deployed with a winch to the target depth and closed via a release mechanism. The closed MSC will placed on deck for a few hours to allow the collected particles to sink to the collection tray. After gently draining the water from the 100 L cylinder, the collection tray containing the settling particles is removed. The collected aggregates will be used to determine their size-specific sinking velocities, microscopic observations of the aggregate composition, and measurements of respiration of the aggregate attached microbes. The aggregate size, sinking velocities, and microbial respiration will be measured on board in a vertical flow chamber at *in-situ* temperature. Individual aggregates will be placed in the flow chamber, whereby the upward flow is increased until the aggregate remains suspended. The sinking velocity of each aggregate is calculated from the flow rate divided by the cross-sectional area of the flow chamber. Microbial respiration will be estimated from the oxygen gradients through the aggregate-water interface measured using a Clark-type oxygen microelectrode mounted in a micromanipulator and calibrated at air-saturation. Similar measurements on zooplankton faecal pellets both from water column and incubations will be carried out.

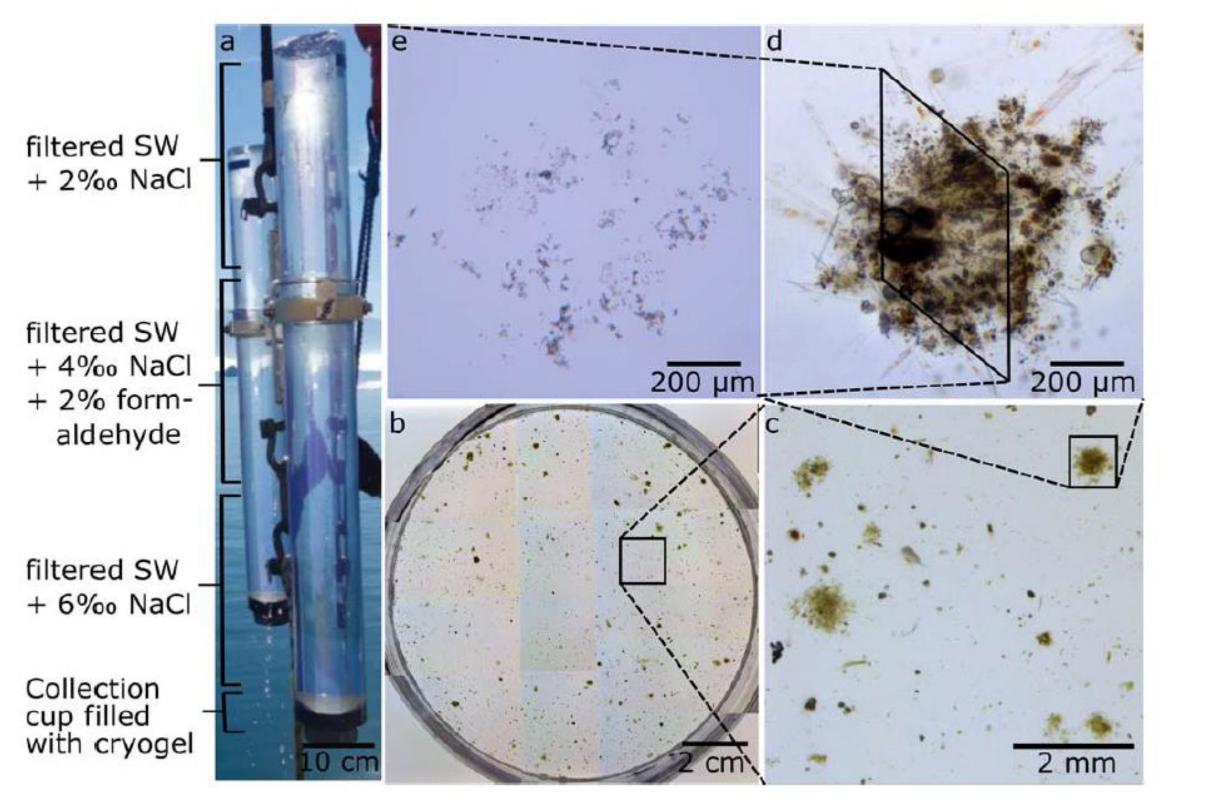

Fig. 12.1: A gel trap containing particles collected in-situ using the drifting trap array

Expected results

The expected data set will determine vertical distribution of aggregates and zooplankton as well as biogeochemical export fluxes in waters surrounding South Georgia and will be compared to similar measurements in open waters carried out in Leg 1. Our study will provide vertical profiles of aggregates and zooplankton at high spatial resolution. Rate measurements of microbial degradation from on-board measurements will help us to identify remineralization processes and by coupling these to *in-situ* flux profiles we can quantify the role of both microbes and zooplankton for flux attenuation. This will allow us to identify important recycling and export processes through the water column. In addition, targeted experimental incubation on board will allow us to follow stoichiometric changes in different pools of organic matter and investigate the role and zooplankton and microbes for trace metals and nutrients in collaboration with the trace metal groups on board during PS133/1 group.

Data management

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

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12.2 Nutrient Cycling in Surface Sediments

Objectives

Our main objective is to understand how turnover of nutrients in surface sediments from different depositional environments impact the water column. Our main focus will be sandy sediments, which are common on shallow shelf systems. In temperate waters, such sediments have been identified as hotspots of biogeochemical activity, with high rates of organic matter degradation, nitrogen turnover and nitrogen loss. They are also zones where porewater advection and sediment redistribution disrupts the traditional redox cascade, which could have a major impact on iron release. So far however, almost nothing is known about these sediments in the Antarctic and their importance in benthic-pelagic coupling. During the voyage we will:

- Measure the dynamics of N-cycling processes in sandy sediments from the shelf and quantify oxygen consumption, nitrification, denitrification/anammox and dissimilatory nitrate reduction to ammonium rates using slurry incubations and flow through reactors
- Compare these rates to those in cohesive sediments using slurry incubations.
- Determine nitrification rates in the water column to better understand the coupling between the pelagic and benthic system
- Compare the microbial communities mediating N-cycling processes in different sediment types/the water column.

Fig. 12.2: Flow through reactor set-up: Flow through cells for determining oxygen concentrations can be seen at the upper and lower inlets of the reactors.

Work at sea

Sediments will be collected using a box corer (primarily sandy sediments) and/or MUC (primarily muddy sediments). The surface layer of the sediments will be separated, homogenized and filled into either flow through reactors (Fig. 12.2) or mixed with seawater (if possible collected from near the sediment surface) in glass bottles to form sediment slurries. Oxygen consumption rates will subsequently be determined using optodes and a suite of experiments using 15N-tracers will allow us to determine nitrogen cycling rates. We will also sample for dissolved iron in collaboration with other groups on board to determine how oxygen and nitrogen cycling processes determine fluxes in and out of the sediment.

To determine water column nitrification rates, samples will be collected from the benthic boundary layer by sampling water overlying the cores retrieved with the MUC and from the mixed layer as sampled using niskin bottles. Time series incubations using 15N-tracers will allow us to determine ammonia oxidation and nitrite oxidation rates, which will be compared to those taken in the open waters sampled on Leg 1. Working together with the marine particles group this will allow us to gain insights into the processes that alter nutrient stoichiometry in the water column.

Preliminary (expected) results

The expected data set will provide oxygen consumption and nitrogen cycling rates for the sediments surrounding South Georgia. Coastal shelf sediments play a key role in global carbon and nutrient cycling, but almost all data so far on sandy shelves has been generated in temperate regions. By filling this knowledge gap for the sediments surrounding South Georgia we will gain important inputs for models that attempt to estimate the global role of these sediments. In addition, targeted incubations on board will allow us to determine the potential for iron transformation and release in these sediments.

Data management

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

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13. ORGANIC GEOCHEMISTRY OF THE WATER COLUMN AND SEDIMENTS

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Grant-No. AWI_PS133/2_12

Objectives

The overarching goal is to characterize and quantify the terrestrial carbon export from South Georgia and how biologically available dissolved Fe affects the biogeochemistry and biological carbon fixation in local shelf waters. Ultimately this information will aid to quantify and qualify the carbon sequestered in fjord sediments. Using radiocarbon analysis paired with molecular characterization of particulate and dissolved organic matter we aim to trace the carbon exported from its likely source on land to depositional sites in the fjords. Biological carbon fixation in shelf waters, mineralization and vertical export to the sediment will further be traced and quantified. Carbon sequestered in the sediments will therefore be a mixture of terrestrial carbon imported laterally and freshly produced marine carbon from the upper water column exported vertically that survive microbial remineralisation. Isotope ($\delta^{13}C$ and $\Delta^{14}C$) mass balance source apportionment models will be applied to quantify the relative proportions of both carbon sources to the sediment and how these changed over time.

For this, soil organic matter will be analysed and its fate along its passage from the site of erosion, through lakes and rivers, towards the fjord sediment will be characterized based on changes in its molecular and isotopic composition. Focusing on abundance and isotopic composition of terrestrial biomarkers (e.g., long chain *n*-alkanoic acids, synthesised by higher land plans), and bulk organic matter will allow to assess the terrestrial organic matter endmember for the carbon sequestration source apportionment model. Similarly, the freshly produced marine endmember will be characterized (e.g., short chain *n*-alkanoic acids, synthesized by algae) based on particulate organic matter collected from the local chlorophyll-*a* maximum. These two endmembers will allow to determine the extent of mixing and remineralisation in the water column and quantify the carbon sequestration in surface sediments. Information gained from the source apportionment model will be applied on short sediment cores from the fjord to investigate how sequestration rates and source proportions changed over time.

Work at sea

Dissolved Inorganic, Dissolved Organic and Particulate Organic Carbon (DIC, DOC, POC)

Radiocarbon analyses of dissolved inorganic carbon and dissolved and particulate organic carbon are useful tracers of carbon cycling mechanisms and carbon reservoir exchange pathways. DIC, DOC and POC constitute major global carbon reservoirs with paramount importance for biogeochemical cycles. Terrestrial material is exported into the oceans largely as DOC and POC, which impacts the composition of marine sediments, a connection that can be used for source appointment utilizing radiocarbon analyses. They have the potential to impact the climate on geological timescales as these reservoirs can sequester carbon for up to millennia and exchange CO_2 at the ocean/atmosphere boundary.

DIC will be sampled applying a novel method developed by members of the Organic Geochemistry working group at AWI. Water obtained with the CTD-Rosette and supernatant water from multi corer (MUC) pipes will be sampled immediately after recovery into pre-combusted 10 ml glass vials. After poisoning with Hg_2Cl, the vials will be crimped shut with rubber membrane lids to prevent CO_2 exchange with the atmosphere. All DIC samples will be taken as duplicates and radiocarbon analyses will be conducted directly on the sealed vials at the MICADAS facility in Bremerhaven.

For DOC sample acquisition, large amounts of water (10 – 30 L) obtained with the CTD-Rosette (for ocean/fjord stations) or with a handheld water sampler (South Georgia lake and creek stations) from different depths will be filtered over pre-combusted Whatman GF/F filters (0.7 µm pore size) using a vacuum pump. The filters retain the POC fraction will be stored frozen till further analysis. An aliquot of the filtrate will be sampled in acid-cleaned 0.5 L brown HDPE bottles and acidified to pH=2 using ultrahigh purity HCl or H_2SO_4. $DO^{14}C$ analyses will be conducted at the MICADAS facility in Bremerhaven upon return.

An array of *in-situ* pumps will be deployed at different stations in the fjords and the open ocean to sample drifting and sinking POC over long periods (several hours). The pumps will be equipped with stacks of pre-combusted glass fiber filters of 0.45 and 0.75 µm pore size. The filters will be used for $PO^{14}C$ analyses as well as molecular mapping of hydrocarbons and lipids and will be stored frozen until extraction and analyses in Bremerhaven.

Surface Water Filtration

To calculate biomarker-based sea surface temperature (SST) reconstruction proxies, sea surface water obtained through an inlet in the ship's bow (~ 5 m.b.s.l.) will be pumped through the internal pipeline system directly to a filtration unit, where it will be passed through a pre-combusted glass fibre filter (Whatman GF/F, 142 mm diameter). Sampling will be conducted during transit times between stations, resulting in large filtration volumes (several hundreds of L). During sampling time, physical parameters (water temperature and salinity) and environmental conditions (weather, SST, air temperature etc.) will be noted. The filters will be dried at 40° C in an oven onboard or will be stored frozen until extraction and analysis, which will be conducted in Bremerhaven.

Sediment sampling

Fjords are accumulation hotspots for organic matter (OM) derived from marine primary production as well as the terrestrial realm adjacent to the fjord. Radiocarbon analyses of bulk sediment samples, specific extractable compounds and pyrolytically derived OM fraction will be conducted to investigate the fate of terrestrial organic matter in fjord settings and increase the understanding of the high latitude carbon cycling. To trace organic matter transportation pathways from land into the ocean, sediment samples will be collected from soil on South Georgia, from lakes on the island and from marine sediments in the fjords. On land, shallow soil samples will be obtained from suitable sites using shovels, while lake sediments will be sampled using a handheld gravity corer. For the marine endmember, the top 0 – 10 cm of MUC cores will be sliced off. The sediment will be stored frozen in pre-combusted honey jars until extraction and analyses.

Expected results

We will generate lateral and vertical profiles of the 14C abundance in the marine carbon pools (POC, DOC, DIC), and pair the isotopic information with molecular characterization of POC and DOC. The expected data set will quantify and characterize terrestrial and marine organic carbon export to the fjord sediments. Further the generated data will allow to examine how organic carbon fluxes varied over the last hundreds of years in response to climatic perturbations.

Data management

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

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

This expedition is supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 2, Subtopic 1, Topic 4, Subtopic 1 and Topic 6, Subtopic 3.

In all publications based on this expedition, the **Grant No. AWI_PS133/2_12** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. http://dx.doi.org/10.17815/jlsrf-3-163.

14. NUTRIENTS AND DISSOLVED ORGANIC MATTER

Kai-Uwe Ludwichowski[1], Erik Stein[1] [1]DE.AWI
not on board: Boris Koch[1], Martin Graeve[1]

Grant-No. AWI_PS133/2_13

Objectives

The determination of nutrients and biogeochemical parameters is closely connected to the physical and planktological investigations. The development of phytoplankton blooms is especially dependent on the available nutrients. Nutrients are also well suited as tracers for the identification of water masses. Our interests on this expedition are focussed to shed light on the sources and transport pathways of Fe and on nutrient distribution in the upper water layer. During the CTD-transects all inorganic nutrients (nitrate, nitrite, ammonium, silicate and phosphate) will be measured in the samples drawn from the rosette bottle system. In addition, dissolved organic matter (DOM) samples will be taken for bulk determinations (DOC/DON) and extracted from seawater using PPL sorbent (enrichment of DOM by solid phase extraction).

Work at sea

From water samples collected with the rosette sampler at various depths, phosphate (Murphy and Riley, 1962), silicate (Strickland and Parsons, 1968), nitrite and nitrate (Grasshoff et al., 1999), and ammonium (Kerouel and Aminot, 1997) will be determined immediately on board using a Seal 500 auto-analyser system according to standard methods. For DOM samples, 500 mL of the seawater sample is filtered through annealed glass fibre filters (Whatman, 450° C, 5 h, 0.7 µm nominal pore size) with a maximum pressure <200 mbar. Aliquots for DOC analyses are stored at –20° C in pre-cleaned high-density polyethylene (HDPE) bottles (Dittmar et al., 2008).

Preliminary (expected) results

This work will investigate the oceanographic coupling between South Georgia and the Antarctic Circumpolar Current ACC, the particle dynamics, and the sources and biogeochemical processes controlling the transport and transformation of ferrous components along the flow path of the ACC. Nutrient data, which will be available about two days after sampling, will allow us to get an overview of water masses, biological activity, and the operation of our sampling system. Later, the nutrient data will be used for many cruise-related studies to reveal a variety of physical and biological processes. Detailed analyses of TOC, DOC/DOM will explore the molecular characteristics and the various terrigenous and marine sources throughout the study area.

Data management

We will sample a large variety of interconnected parameters. We plan that the full data set will be available at least one year after the cruise. Most of the samples, which will not be analyzed immediately, will be stored at AWI and will be available to other colleagues. Data will be made available to the public via the PANGAEA repository after a two years embargo period.

This expedition is supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 2, Subtopic 1, Topic 4, Subtopic 1 and Topic 6, Subtopic 3.

In all publications based on this expedition, the **Grant No. AWI_PS133/2_13** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. http://dx.doi.org/10.17815/jlsrf-3-163.

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APPENDIX

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

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A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
Anderson	Madeline	UK.BAS	PhD Student	Biology
Anselin	Josephine	UK.BAS	PhD Student	Oceanography
Bussmann	Ingeborg	DE.AWI	Scientist	Geology
Chang	Jun Hao	DE.UNI-Köln	PhD Student	Geochemistry
Colias Blanco	Manuel	DE.NHC	Technician	Helikopter Service
Dohrmann	Ingrid	DE.AWI	Technician	Geochemistry
Ebner	Berenice	DE.AWI	PhD Student	Geochemistry
Geibert	Walter	DE.AWI	Scientist	Geochemistry
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Glawatty	Tanja	DE.AWI	Administrative Assistence	Biology
Graham	Alastair	GOV.FLORIDA	Scientist	Geophysics
Grotheer	Hendrik	DE.AWI	Scientist	Geochemistry
Höhn	Malte	DE.AWI	Engineer	Geochemistry
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Iversen	Morten	DE.AWI	Scientist	Biology
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Koehler	Dennis	DE.AWI	Engineer	Geochemistry
Koehler	Neele	DE.UNI-Bremen	Student	Geology
Köster	Male	DE.AWI	Scientist	Geochemistry
Krock	Bernd	DE.AWI	Scientist	Chemistry
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Otte	Frank	DE.DWD	Scientist	Meteorology
Porrmann	Simon	DE.AWI	Student	Geophysics
Rubiano	Catalina	GOV.FLORIDA	Student	Oceanography

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
Schaubensteiner	Stefan	DE.NHC	Pilot	Helikopter Service
Sekudewicz	Ilona	PAN	PhD Student	Geochemistry
Spahic	Susanne	DE.AWI	Technician	Biology
Staubwasser	Michael	DE.UNI-Köln	Scientist	Geochemistry
Stein	Erik	DE.AWI	Technician	Chemistry
Stimac	Ingrid	DE.AWI	Technician	Geochemistry
Stimpfle	Jasmin	DE.AWI	PhD Student	Biology
Streuff	Katharina	DE.UNI-Bremen	Scientist	Geology
Weiss	Josefine-Friederike	DE.AWI	PhD Student	Biology
Wilkie	Isabella	DE.MPIMM	PhD Student	Biology
Willis Poratti	Graciana	AR.IAA	Scientist	Biology
Wunder	Lea	DE.UNI-Bremen	PhD Student	Biology

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

Name	Vorname	Position
Langhinrichs	Moritz	Master
Langhinrichs	Jacob	Chiefmate
Ziemann	Olaf	Chiefmate Cargo
Eckenfels	Hannes	Chief
Strauß	Erik	2nd Mate
Peine	Lutz	2nd Mate
Dr. Guba	Klaus	Ships Doc
Dr. Hofmanng	Jörg	SET
Ehrke,	Tom	2nd. Eng
Krinfeld	Oleksandr	2nd. Eng
Rusch	Torben	2nd. Eng
Pommerencke	Bernd	SET
Frank	Gerhard	ELO
Schwedka	Thorsten	ELO
Winter	Andreas	ELO
Krüger	Lars	ELO
Brück	Sebastian	Bosun
TBN		Carpen.
Möller	Falko	MP Rat.
Buchholz	Joscha	MP Rat.
Schade	Tom	MP Rat.
Decker	Jens	MP Rat.
Fink	Anna-Maria	MP Rat.
Weiß	Daniel	MP Rat.
Niebuhr	Tim	MP Rat.
Lutz	Johannes	MP Rat.
TBN		MP Rat.
TBN		MP Rat.
TBN	Niklas	MP Rat.
Clasen	Nils	MP Rat.
Arnold-Becker	André	MP Rat.
Waterstradt	Felix	MP Rat.

Name	Vorname	Position
Plehn	Marco Markus	Storek.
Schnieder	Sven	Cook
TBN		Cooksm.
Martens	Michael	Cooksm.
Witusch	Petra	Chief Stew.
Ilk	Romy	Nurse
Fehrenbach	Martina	2nd Stew
Golla	Gerald	2nd Stew
TBN		2nd Stew
Shi	Wubo	2nd Stew
Chen	Quan	2nd Stew
Hu	Guo Yong	Laundym