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

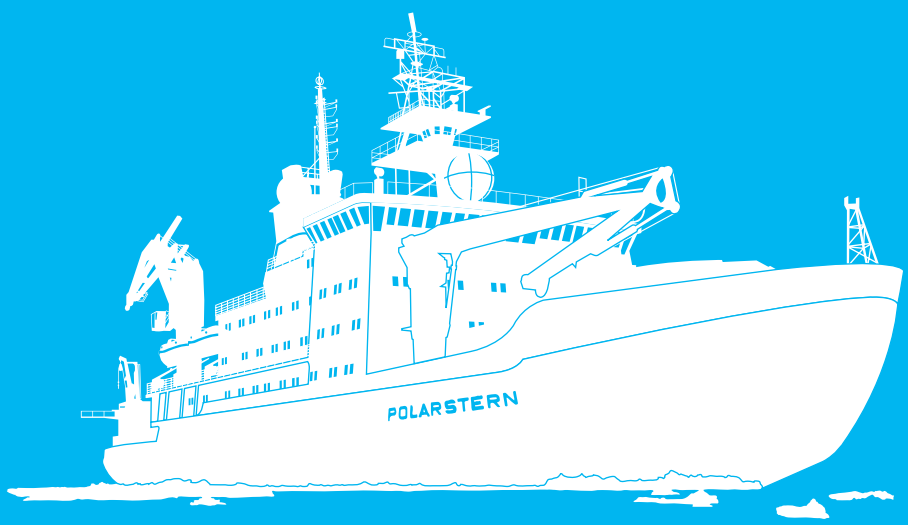
EXPEDITION PROGRAMME PS133/1

# Polarstern

**PS133/1**
**Cape Town – Punta Arenas**
**01 October 2022 – 17 November 2022**

Coordinator: Ingo Schewe

Chief Scientist: Christine Klaas

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# Expedition PS-133/1 Island Impact Leg 1

**01 October 2022 – 17 November 2022**

**Cape Town – Punta Arenas**

**Chief scientist**
**Christine Klaas**

**Coordinator**
**Ingo Schewe**

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# 1. ÜBERBLICK UND FAHRTVERLAUF

Christine Klaas DE.AWI

Grundlagenforschung in den Bereichen physikalische, biologische und chemische Ozeanographie und geochemische und biogeochemische Untersuchungen der Tiefsee stehen im Zentrum der *Polarstern*-Expedition PS133/1. Die Expedition umfasst zwei Projekte: (1) „Island Impact“ (Abschnitt 1) ist ein multidisziplinäres Projekt, das den Input und Transport von Eisen aus kontinentalen Schelfen, insbesondere von Südgeorgien untersucht und quantifiziert. Der Einfluss von Eisen auf die pelagische Produktion, die Kohlenstoffaufnahme und den -export, die Zusammensetzung des Planktons und die Biogeochemie in der Wassersäule und in marinen Sedimenten im Antaktischen Zirkumpolarstrom (ACC) im Luv von Südgeorgien bilden Schwerpunkte der Untersuchung. ("Island Impact" wird ergänzt durch Abschnitt 2, bei dem Eisenquellen auf und um Südgeorgien studiert werden.) (2) Im Projekt „South Polar Carbon“ werden biogeochemische Flüsse und biogeochemische Prozesse in marinen Sedimenten im South Sandwich Tiefseegrabensystem untersucht. Beide Projekte addressieren wesentliche Ziele, die im neuen Forschungprogrammem „Changing Earth – Sustaining our Future” des Forschungsfeldes “Erde und Umwelt” der Helmholtz Gemeinschaft in den Topics 2 (“Ocean and Cryosphere in Climate”), 4 („Coastal Transition Zones under Natural and Human Pressure“) und 6 („Marine and Polar Life: Sustaining Biodiversity, Biotic Interactions and Biogeochemical Functions“) formuliert worden sind.

Der Atlantische Sektor ist wohl die produktivste Region des Südpolarmeeres. Er beherbergt den größten Krillbestand rund um die Antarktis und die Antarktischen Inseln und mit die größten Kohlenstoffaufnahmen und -flüsse bis zu den Tiefseesedimenten. Paradoxerweise ist das Südpolarmeer gleichzeitig das größte HNLC-Gebiet des Weltozeans (HNLC = high nutrient low chlorophyll, d.h. hohe Nährstoff- und geringe Chlorophyll-Konzentrationen), wo Makronährstoffe (Nitrat, Phosphat, Kieselsäure) nie aufgezehrt werden, da die Primärproduktion durch Eisenmangel limitiert ist. Hochproduktivgebiete breiten sich entlang des südlichen ACC (S-ACC) auf den Luvseiten von Landmassen aus. Dies deutet auf einen starken Einfluss von Eiseneintrag von der Antarktischen Halbinsel und von Inseln auf die biologische Produktion und den Kohlenstoffexport in der Scotia Sea hin. Weiter nördlich erstreckt sich ein Hochproduktionsfahne von den Schelfgebieten Südgorgiens über einen Großteil des Atlantischen Sektors: ein Hinweis auf den Einfluß des von der Insel stammenden Eiseneintrags auf biogeochemische Prozesse im S-ACC (Abb. 1.1 A). Ein direkter Zusammenhang zwischen Südgeorgien als Fe-Quelle und der Blüte im S-ACC wird jedoch weder in Modellsimulationen reproduziert noch durch Feldstudien gestützt, da es an Feldbeobachtungen und Kenntnissen über die relevanten Prozesse mangelt. Außerdem zeigt die Chlorophyll-a-Saisonalität ein deutliches Muster mit verzögertem Auftreten der Blüte und geringerer Biomasse östlich des Georgia-Beckens (Abb. 1.1 A und B). Dieser Verlauf könnte durch unterschiedlichen Eiseneintrag (variiert mit Abstand von der Insel; Venables & Meredith, 2009) oder durch Unterschiede in anderen umweltbedingten Antrieben erklärt werden, was zu geringer Akkumulation von Biomasse und geringerem Export führt. Unsere Ziele sind daher, besseres Erkenntnisse zu bekommen über:

- Verteilung, Speziation und biologische Verfügbarkeit von Eisen und anderen Spurenmetallen in der Wassersäule.

- Photophysiologischen Status, Spurenmetallaufnahme und Spurenmetallanteil in Phytoplankton als Indikatoren der Eisenverfügbarkeit.
- Bestimmung des Einflusses anderer Umweltparameter auf die Produktivität und Biogeochemie (einschließlich der Aufnahme von atmosphärischen Kohlendioxid). Dies schließt insbesondere ein: Tiefe der durchmischten Schicht und Stabiliät über relevante Zeitskalen, andere Mikro- und Makronährstoffe, Planktonprozesse wie Wachstum, Mortalität und Lebenszyklen von Schlüsselarten im Phyto- und Zooplankton.
- Untersuchung der Partikeldynamik inklusive der Sedimentationsflüsse, Partikel-Aggregation, der mikrobiellen Degradationsraten und den Beitrag des Zooplanktons zum vertikalen Export (flux feeding, Kotballenproduktion); Abschätzung der Sedimentations-flüsse; explizite Verknüpfung von Partikeldynamik mit Planktonzusammensetzung und -dynamik sowie Export von Fe, Si, N und C.
- Bestimmung von Eisenquellen und Mechanismen von physikalischem Eisen- und Nährstofftransport; Abschätzung von physikalischen Mischungsprozessen (regional bis hinunter zu submesoskalisch) auf den Schelfkanten Südgeorgiens und im luvseitigen S-ACC.
- Kombination der Raten von biogeochemischen Prozessen mit physischem Transport und Durchmischung, um den Einfluss dieser Faktoren auf räumliche und zeitliche Skalen in Südgeorgien und im "Kielwasser" der Insel zu bemessen.

Um die physikalischen und biogeochemischen Prozesse im Kielwasser von Südgeorgien zu verstehen, werden fünf Schnitte (S1 bis S5, Abb. 1.1C) über den Hauptteil des ACC (zwischen der Polarfront und der Südlichen ACC-Front) durchgeführt. Jeder Schnitt beinhaltet auf dem Hinweg hoch aufgelöste Messungen mit zahlreichen Sensoren auf einem Top-AWI MacArtney Triaxus Schleppsystem (TRIAXUS) in den oberen 350 Metern der Wassersäule und auf dem Rückweg Stationen mit Wasserproben und Netzen im Abstand von 30 Seemeilen. An sechs bis sieben ausgesuchten Orten sind längere Stationen mit Prozessstudien („process stations“) und Messungen von Flüssen von der Oberfläche bis zu den Tiefseesedimenten geplant.

*South Polar Carbon*

Obwohl Gräben nur weniger als 2 % des Meeresbodens bedecken, fungieren sie als Ablagerungszentren (Sedimentfokusierung) für organisches Material, aber auch für Schadstoffe. Der extreme hydrostatische Druck, ihre besondere Bathymetrie und Isolationen befördern Endemismus. *In-situ* Untersuchungen haben kürzlich ergeben, dass Tiefseegräben als diagnostische "Hot-Spots" fungieren können und dass ihre Sedimente typischerweise im Vergleich zu der umgebenden Tiefsee sehr hohe Anzahlen von Mikroben enthalten. Viele Tiefseeregionen – insbesondere Tiefseegräben mit ihrer einzigartigen Ablagerungsdynamik – sind bisher kaum untersucht. Der South Sandwich Graben ist das tiefste Grabensystem im Südpolarmeer. Es erstreckt sich über eine Länge von 1.450 km und besitzt eine maximate Tiefe von 8266 m (Meteor Deep; Jamieson, 2015). Sedimente an der Grabenkante (etwa 6300 m Tiefe) besitzen erhöhte Meiofaunaabundanzen, die auf erhöhte Nahrungszufuhr hinweisen (Vanhove et al., 2004), aber das Innere des Graben ist bisher praktisch nicht untersucht.

In dieser Expedition wollen wir die Biogeochemie (Mikrobiel und Meiofauna) und Geochemie, den Eintrag von Schadstoffen in der Tiefsee, in den Sedimenten der Tiefseeebenen und in Tiefseegräben untersuchen. Wir wollen den Kohlenstoffeintrag und die Remineralisierung in diesen Systemen quantifizieren (s. Prozessstudien in Abb. 1.1C und Tiefseestationen im South Sandwich Graben). Die Ergebnisse werden zu unserer wachsenden Datenbasis über Bedingungen in der Tiefsee beitragen und uns erlauben, die Produktivität und den vertikalen

Kohlenstofftransport in den genannten Systemen zu verfolgen. Die Einsichten aus der Untersuchung des South Sandwich Grabens sollen verglichen werden mit denen aus dem eutrophen Atacama Graben und dem oligothrophen Karmadec Graben. Zusammen wird dies einen generischen Einblick in die biogeochemische Funktion und Artenzusammensetzung in Tiefseegräben ermöglichen. Diese Untersuchung ist eingebettet in ein Netzwerk aus internationalen Zusammenarbeiten und Forschungsprogrammemen und insbesondere verbunden mit dem laufenden ERC-Advanced Grant **HADES** (“Benthic diagenesis and microbiology of hadal trenches”; Grant-Nr. 669947).

Die Expedition PS133/1 mit *Polarstern* wird am 1. Oktober in Kapstadt beginnen und den ersten Island Impact Schnitt bei 7° W and 52° S ansteuern (S1, Abb. 1.1C). Ein zweiter Schnitt beginnt bei etwa 19°30‘W, 55°‘S. Danach werden wir den South Sandwich Graben ansteuern, um dort die South Polar Carbon Studie durchzuführen. Die South Polar Carbon Studie wird 3 bis 4 Tage dauern und bis zu 6 Station umfassen – im Süden bei 57°26‘S beginnend und dann endend bei 28°57‘W 54°3.6‘S dem South Sandwich Graben nordwärts folgend. Nach dem Abstecher zum South Sandwich Graben werden wir die Island Impact Aktivitäten in Form von drei weiteren Schnitten wieder aufnehmen: ein Nord-Süd Schnitt (S3, Abb. 1.1C) bei 31°40‘W, ein Ost-West Schnitt (S4, Abb.1.1C) entlang der Schelfkante von Südgeorgien und schließlich ein Südost-Nordwest Schnitt (S5, Abb. 1.1C) im Georgia Basin. Danach nehmen wir Kurs auf Punta Arenas, wo wir am 17. November 2022 ankommen werden.

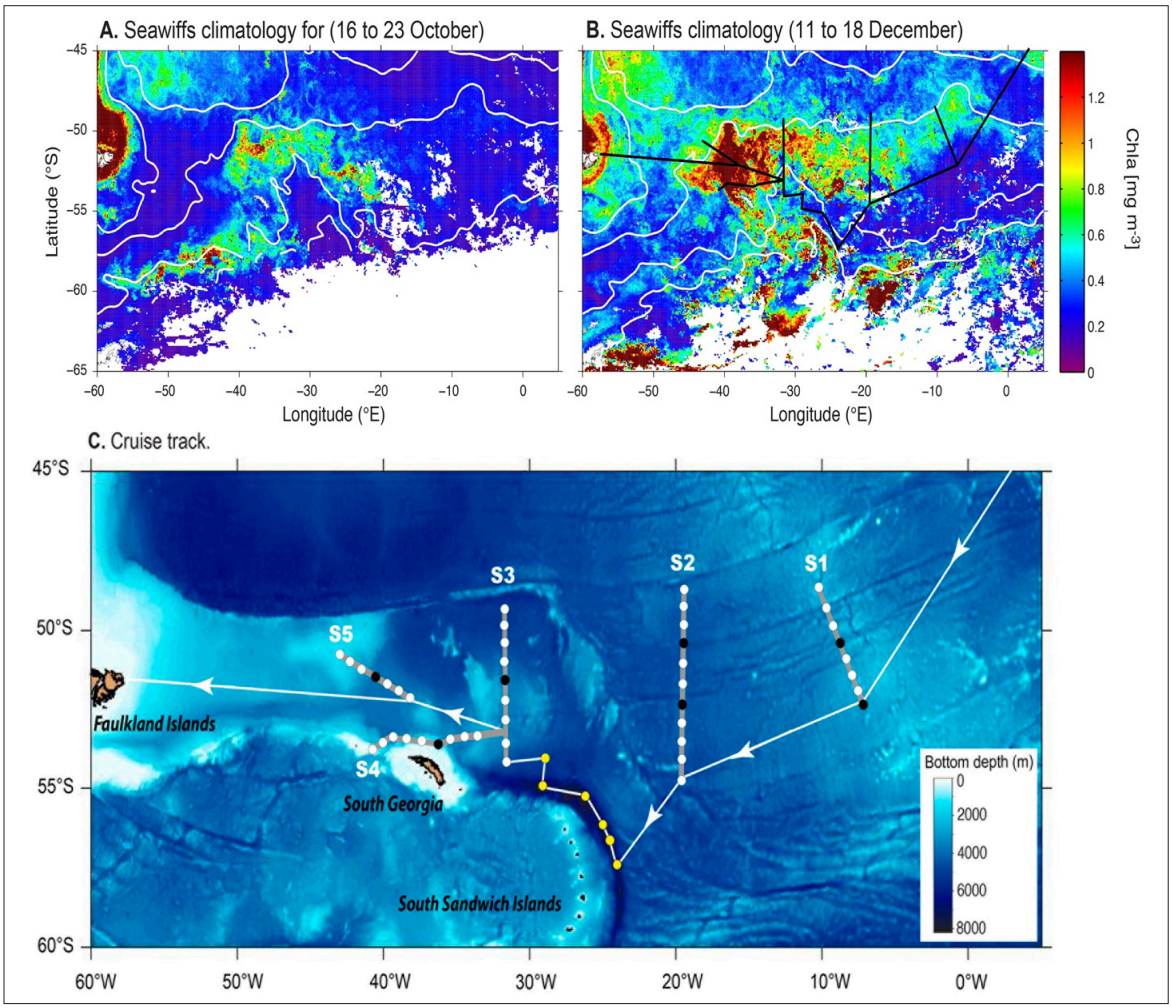


*Abb. 1.1: Übersichtskarte des Untersuchungsgebiets und Fahrtroute mit A) 8-Tage-Chlorophyll-a-Klimatologie aus SeaWifs (Zeitraum 1997–2010) zu Beginn der Wachstumssaison (Mitte Oktober) und B) auf dem Höhepunkt der Wachstumssaison (Dezember) sowie PS133/1 Fahrtroute (schwarze Linien); die weißen Linien zeigen die Positionen der Fronten (basierend auf der dynamischen Höhe) – von Norden nach Süden: die subantarktische Front, die Polarfront, die südliche ACC-Front und die südliche Grenze. Beachten Sie, dass das Maximum der Chl a-Farbskala auf 1,4 mg $m^{-3}$ gesetzt wurde, um die Produktivität in Gebieten des offenen Ozeans hervorzuheben, in denen trotz relativ niedriger Chl a-Konzentrationen die vertikal integrierten Bestände aufgrund tiefer Durchmischungsschichten hoch sind. C) Übersichtskarte der Fahrtroute (weiße Linie); die Lage der Island-Impact-Abschnitte (S1-S5) ist durch die grauen Linien gekennzeichnet, die Probenahmestationen durch die weißen Kreise. Die vorläufigen Positionen für die erweiterten Prozessstudien („Prozessstationen“) sind durch die schwarzen Kreise gekennzeichnet und die gelben Punkte markieren die Hadal- und Abyssal-Stationen für das South Polar Carbon-Projekt.*

*Fig. 1.1: General map of the study region and cruise track showing A) 8-day chlorophyll a climatology obtained from SeaWifs (period 1997–2010) at the early growth season (mid-October) and B) at the height of the growth season (December) and PS133/1 cruise track (black lines). White lines indicate positions of the fronts (based on dynamic height); from North to South: the Subantarctic Front, Polar Front, Southern ACC Front and the Southern Boundary. Note that the maximum in the Chl a colorscale has been set to 1.4 mg $m^{-3}$ to highlight productivity in open ocean areas where, despite relatively low Chl a concentrations, vertically integrated standing stocks are high due to deep mixed layers. C) General map of the cruise track (white line). Location of the Island Impact sections (S1-S5) are indicted by the grey lines, sampling stations by the white circles. Preliminary position for the extended process studies (“process stations”) are indicated by the black circles, respectively. Yellow dots mark the Hadal and Abyssal stations for the South Polar Carbon project.*

## SUMMARY AND ITINERARY

The aims of the expedition PS133/1 on board *Polarstern*, is to perform basic research in physical, biological, chemical oceanography and deep-sea geo- and biogeochemistry. The expedition encompasses two projects: 1) “Island Impact” Leg 1: a multidisciplinary project to study and quantify iron inputs and transport from the continental shelves and slope of South Georgia and the impacts on surface productivity and carbon uptake and export, plankton communities, water column and sediment biogeochemistry along the downstream flow of the Southern Antarctic Circumpolar Current in the Atlantic sector of the Southern Ocean. (Island Impact is a larger effort encompassing an additional study – Island Impact Leg 2 (PS133/2) – on iron sources in South Georgia). 2) “South Polar Carbon”: will study biogeochemical fluxes and deep-sea biogeochemistry of sediments in bathyal to hadal sites of the South Sandwich Trench system. Taken together both project address important goals defined in the new programmeme “Changing Earth – Sustaining our Future” in the research field “Earth and Environment” of the Helmholtz Association for Topic 2: “Ocean and Cryosphere in Climate” Topic 4: “Coastal Transition Zones under Natural and Human Pressure” and Topic 6: “Marine and Polar Life: Sustaining Biodiversity, Biotic Interactions and Biogeochemical Functions”.

The Atlantic sector is arguably the most productive region in the Southern Ocean (SO), sustaining the largest krill stocks around the continent and islands, as well as some of the highest carbon uptake and fluxes to deep-sea sediments. Paradoxically, the Southern Ocean corresponds also to the largest high nutrient low chlorophyll (HNLC) region of the world’s oceans, where macronutrient (nitrate, phosphate, silicate) concentrations remain high, due to iron limitation of phytoplankton productivity. Along the flow of the Southern ACC (S-ACC), areas of high productivity extend as plumes downstream of landmasses, suggesting a strong influence of iron input from the Antarctic Peninsula and islands on productivity and carbon export in the Scotia Sea. Further north a high productivity plume extending from the shelves of South Georgia over most of the Altantic Sector indicates a possible influence of the Island derived iron supply on downstream S-ACC biogeochemical processes (Fig. 1.1A). A direct linkage between South Georgia as a Fe source and blooms in the S-ACC is, however, not reproduced in model simulations or supported by field studies due to the lack of field observations and knowledge of relevant processes. Further, chlorophyll *a* seasonality show a distinct pattern with delayed bloom occurrence and lower biomass eastward of the Georgia Basin (Fig.1.1 A and B). This could be due to differences in Fe supply (with increasing distance from the island; Venables and Meredith, 2009) or differences in other environmental drivers leading to slower biomass accumulation and lower export. Our purpose is therefore to gain better knowledge of:

- Spatial distribution of Iron and other trace metals, their speciation and bioavailability in the water column.
- Assess the photophysiological status, trace metal uptake rates and trace metal quotas in phytoplankton as indirect indicator of Fe availability.
- Determine the impact of other environmental parameters on productivity and biogeochemistry (including atmospheric carbon uptake): these include mixed layer depths and their stability over relevant time frames, other micro and macronutrients, and plankton interactions including growth, mortality and life cycles of key phytoplankton and zooplankton species or assemblages.

- Investigate particle dynamics including sedimentation fluxes, particle aggregation, microbial degradation rates and contribution by zooplankton (flux feeding and faecal pellet production) to the vertical export. Estimate sedimentation fluxes. Link particle dynamics explicitly with plankton composition, dynamics and export of Fe, Si, N and C.
- Determine Fe sources and mechanisms of physical Fe and nutrient transport and key physical mixing processes (from regional to the submesoscale) between the South Georgia shelf and the downstream flowing S-ACC.
- Compare and combine rates of biogeochemical processes with physical transport and mixing to assess the importance of these drivers at different spatial and temporal scales in South Georgia and further downstream.

In order to understand physical and biogeochemical processes influencing carbon and nutrient cycles and export downstream of South Georgia, five sections (S1 to S5, Fig. 1.1C) across the main flow of the ACC (between the Polar Front and the Southern ACC front) will be carried out. Each section will encompass in one direction measurements with sensors mounted on a Top-AWI MacArtney Triaxus towed undulating remotely operated vehicle (TRIAXUS) for high resolution measurements of water column (0 to 350 m depth) physical and biogeochemical properties followed by station activities (water and net sampling) at an approximate distance of 30 nm on the way back. At six to seven selected locations along the cruise track, longer station work is planned to include process and flux measurements from the surface down to the deep-sea sediments ("process stations").

*South Polar Carbon*

Trenches only account for less than 2 % of the global seabed area, however, they have been shown to act as deposition centers (via sediment focusing) for organic material but also marine pollutants. Furthermore, the extreme hydrostatic pressure, their distinct bathymetry and isolation facilitate endemism in trench environments. Recent *in-situ* investigations have also documented that trenches act as diagenetic hots-spots in the deep sea and that hadal sediments typically host high microbial cell numbers as compared to adjacent abyssal settings. Many areas of the deep sea – in particular trenches with unique deposition dynamics – are still poorly explored. The South Sandwich Trench is the deepest trench system of the Southern Ocean and stretches over 1,450 km with a maximum depth of 8,266 m (Meteor Deep; Jamieson, 2015). Sediments at the rim of the trench (~6,300 m) show enriched meiofaunal abundances suggesting intensified food supply (Vanhove et al., 2004), but the trench interior remains largely unexplored.

During this expedition, we aim to study the bio- (microbial and meiofauna) and geochemistry and pollutants as well as quantify the carbon supply and remineralisation of bathyal, abyssal and hadal sediments by combining measurements at the bathyal stations in the S-ACC (process stations in Fig. 1.1C) with the study of abyssal and hadal systems in the South Sandwich Trench. The result will add to our growing database on conditions in the deep sea and allow for comparison between bathyal to hadal environments experiencing different regimes of productivity and vertical carbon export. The insight from the hadal study will be compared to similar investigations that we have conducted in the eutrophic Atacama Trench and oligotrophic Kermadec Trench region. This will provide a generic insight on biogeochemical function and community compositions in hadal trench regions. This study is embedded in a network of international collaborations and research programmes and linked to the activities of an ongoing ERC-Advanced Grant **HADES** ("Benthic diagenesis and microbiology of hadal trenches"; Grant-Nr. 669947).

The expedition PS133/1 will leave Cape Town on board *Polarstern* on 1 October 2022 heading southwest towards the first section of Island Impact (S1, Fig. 1.1C) starting at about 7° W and 52° S followed by a second section at approximately 19° 30'W, 55° S, respectively. Following these we will head towards the South Sandwich Trench to carry out the South Polar Carbon study. The South Polar Carbon study will last 3 to 4 days with up to 6 stations starting south at 57° 26'S and along the South Sandwich Trench veering north to 28° 57'W 54° 3.6'S. After work in the South Sandwich Trench, we will resume the Island Impact activities with three sections: a north-south section (S3, Fig. 1.1C) at 31° 40'W, an east-west section (S4, Fig. 1.1C) along the Shelf break of South Georgia and a final southeast to northwest section (S5, Fig. 1.1C) in the Georgia Basin before heading to Punta Arenas where we should arrive on 17 November 2022.

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# 2. PHYSICAL OCEANOGRAPHY

Wilken-Jon von Appen[1], Jens Hölemann[1], Hauke Becker[1], Lilian Dove[2], Ryan Mole[1], Annika Oetjens[1], Anna Hölemann[1,3]

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**Grant-No. AWI_PS133/1_02**

## Objectives

The Antarctic Cirumpolar Current (ACC) features many strong fronts that supress the exchange of tracers across them. Therefore, tracers (such as for example iron from South Georgia) injected between two fronts, to first order, remain between those two fronts. Hence it is important to understand second order mesoscale and submesoscale processes such as instabilities and eddies that facilitate cross-frontal exchange and thereby the injection of iron into parts of the ocean that might otherwise be micro-nutrient limited. Synoptic sections, especially at high spatial resolution, are an important tool to study these processes, particularly the interplay between physical, biogeochemical and biological processes. Due to the remoteness and harshness of the environment, there is a dearth of such observations in the Atlantic sector of the ACC. We aim to collect measurements that will address this lack of observational data. In addition to analyses inherently based on these planned observations, the data will also be an important constraint on model simulations of the region.

## Work at sea

We aim to occupy up to 5 sections (S1-S5) across the ACC with the best vertical and horizontal resolution for physical and chemical/biological parameters. The goal is to travel along each of the sections twice. The first occupation will collect towed observations and the second occupation will collect station-based observations. At all times underway measurements with the vessel mounted ADCP (for upper ocean horizontal ocean velocity) and the thermosalinograph (for temperature and salinity) will be collected.

The stations will involve casts with the regular (non-clean) CTD to the bottom or to 1,000 m depth. This CTD also contains a lowered ADCP (for whole water column horizontal ocean velocity). An ultra-clean CTD-rosette system will also be deployed down to 1,000 m depth for the sampling of trace metals.

The towed observations will be achieved with the Top-AWI MacArtney Triaxus towed undulating remotely operated vehicle. It is equipped with CTD sensors in addition to a number of other sensors and should provide interdisciplinary section data similar to von Appen et al. (2020). The upper 300 to 350 m of the water column will be sampled at a horizontal resolution of < 2,000 m. In case the Triaxus operation should not be possible, we will deploy the underway CTD which should provide a more limited (physics only) set of data similar to von Appen et al (2018).

During towed transects we will collect water samples from the ship's intake to examine the micro-phytoplankton community composition and derive estimates of the phytoplankton size distribution using a PlanktoScope high-throughput imaging microscope.

In the vicinity of South Georgia, near the end of the cruise, we will deploy four surface drifters drogued at 15 m to elucidate pathways of the upwelled water along the ACC.

### Preliminary (expected) results

We expect multiple high resolution (in space and in terms of amount of covered relevant physical, chemical, and biological parameters) sections of the ACC that have not been available hitherto. They will elucidate cross-frontal exchange processes and how the iron and the phytoplankton distribution depend on the water masses and frontal features. Furthermore, we will see explicit near-surface Lagrangian pathways emanating from 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.

This expedition is supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 2, Subtopic 1 and Topic 6, Subtopic 3, and additional funding by HGF/INSPIRES to project “PACC”.

In all publications based on this expedition, the **Grant No. AWI_PS133/1_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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Von Appen W-J, Strass VH, Bracher A, Xi H, Hörstmann C, Iversen M, Waite A (2020) High-resolution physical-biogeochemical structure of a filament and an eddy of upwelled water off Northwest Africa. Ocean Science 16:253–270. https://doi.org/10.5194/os-16-253-2020

# 3. NUTRIENTS

Kai-Uwe Ludwichowski[1], Matthias Woll[1]; [1]DE.AWI
not on board: Martin Graeve[1]

**Grant-No. AWI_PS133/1_03**

## Objectives

The determination of nutrients and biogeochemical parameters is closely connected with 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 on the nutrient distribution in the upper water layer and the interactions between phytoplankton and nutrients during the development of phytoplankton blooms. 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, the stable isotope ratios of nitrogen and carbon for biogenic substances in the surface layers will be investigated to describe the isotopic structure of the Antarctic ecosystem and to trace the flow of sea-ice-derived matter contributing substantially to the suspended pelagic biomass especially during the late season.

## Work at sea

From water samples taken with the rosette sampler at different depth, the nutrients phosphate (Murphy & Riley, 1962), silicate (Strickland & Parsons, 1968), nitrite and nitrate (Grasshoff et al., 1983) and ammonium (Kerouel & Aminot, 1997) are determined immediately on board using a Seal 500 auto-analyser system according to standard methods. Particulate organic matter for bulk stable isotope analysis of $^{13}C$ and $^{15}N$ isotopes will be obtained by standard methods after filtration onto precombusted GF/F filters.

## Preliminary (expected) results

This work will be carried out to continue the investigation of the seasonal as well as the interannual variability of the Antarctic Circumpolar Current (ACC) and the Weddell Gyre. With the help of the nutrient data, that will be available approximately within two days after sampling, we will get an overview of water masses, biological activity and functioning of the sampling system. Nutrient data will be also used to elucidate both physical and biological processes, i.e. determine seasonal nutrient budgets, nutrient uptake ratios as a function of plankton community composition and trace metal availability, grazer activity, remineralisation and physical transport and mixing processes. Analysis of $\delta^{13}C / \delta^{15}N$-POM will highlight the interaction between sympagic and pelagic communities

## 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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# 4. TRACE METAL DISTRIBUTION AND BIOGEOCHEMISTRY IN THE OPEN WATERS DOWNSTREAM OF SOUTH GEORGIA

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not on board: Andrew Allen[2], Harald Biester [3], Susann Henkel[1], Florian Koch[1], Mak Saito[5], Michael Staubwasser[6]

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**Grant-No. AWI_PS133/1_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 fuelling 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 fueling the large blooms along the S-ACC downstream of South Georgia are: i) Advection or entrainment through winter mixing of Fe-enriched deep waters originating around South Georgia. 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 for phytoplankton the Fe in the different pools is. Finally we will further study the fate of other trace metals, in particular mercury (Hg). Primary productivity and uptake by algae is suggested to be a critical vector of the biomagnification of Hg in the marine food chain. We will investigate the relation between Hg algae scavenging and Methyl-Hg formation in the water column with the bioaccumulation in the trophic web and the final accumulation in the sediments.

In order to fulfill our goals during PS133/1 we will:

- characterise the Fe distribution patterns, stocks along the water column
- determine Fe isotope fractionation between dissolved and suspended Fe to identify potential mineral Fe sources and internal Fe cycling
- 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, quantify transcriptional abundance to link iron uptake rates and iron acquisition strategies to specific phytoplankton taxonomic groups, determine the Fe bioavailability of different Fe sources (deep water, hydrothermal influenced seawater, grazing products from copepods) through 24 h incubation experiments
- characterise the mercury (Hg) and Methyl-Hg distribution patterns (in sinking particular material (phyto- and zooplankton) and water) along the water column as well as along the large scale gradients in productivity
- determine the role of sinking particles on the Methyl-Hg distribution on the water column and how changes in the primary production can affect them

**Work at sea**

In order to characterise trace metal chemistry (dissolved and particulate Fe, dissolved and particulate Fe isotopes, Fe chemical speciation, concentrations of ligands and humic-acid like substances and mercury) seawater will be sampled at 45 stations along depth profiles using trace metal clean sampling infrastructure including a Teflon CTD equipped with OTE bottles (12 L/bottle capacity) and winch. More specifically:

- At 21 shallow stations we will collect seawater to determine concentrations of dissolved trace metals (Fe, Mn, Zn, Co and Cu), particulate Fe and Fe chemical along the water column.
- At 17 deep stations (0–1,000 m, 10 depths), we will collect seawater to determine concentrations of dissolved trace metals (Fe, Mn, Zn, Co, Cu and Hg), particulate Fe, humic acid-like substances and Fe chemical speciation from each depth. Samples for Hg will be only collected at 3 of the stations.
- At the process stations (0 m– bottom, 16 depths), 2 ultra-clean CTD casts will be required to sample for concentrations of dissolved trace metals (Fe, Mn, Zn, Co, Cu and Hg), particulate Fe, ligands, humic acid-like substances and Fe chemical speciation from each depth. Samples for Hg will be collected only at 3 of the stations. From 8 depths, we will sample for dissolved and particulate Fe isotopes. Samples for colloidal Fe will be taken at 20 m depth and the metal contents and taxonomic identities of dissolved extracellular proteins will be determined.
- At 3 process stations and 1 deep station (0–1,000 m, 8 depths), we will collect 10 L seawater. Each sample will be filtered through individual 0.2 µm filter capsules. The filter capsules will be stored and leached for reactive Fe phases after the cruise.

At each station, from 20 m depth, we will also determine primary- and bacterial production rates, Fe uptake rates, trace metal (Fe, Mn, Zn, Co and Cu) quotas, photophysiological status, transcriptional abundance (both bacterial and eukaryotic), and *in-situ* diatom species-specific growth rate. Size fractionated (0.2–2, 2–20 and 20 µm) primary- and bacterial production rates will be estimated using $^{14}$C-bicarbonate and $^{3}$H-leucine, respectively. In addition, uptake rates of Fe and $B_{12}$ will be measured using $^{55}$Fe and $^{57}$Co-$B_{12}$. The photophysiological status of the sampled phytoplankton community will be determined on board using a Fast repetition rate fluorometer. Lastly, total transcriptional abundance (both bacterial and eukaryotic) at 20 m depth will be quantified and characterised.

At 2 stations, seawater will be pumped on board with the help of a Teflon membrane pump through a LDPE Hose will be lowered to 20 m. Approximately 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). All bottles will be incubated in climate-controlled laboratories.

At 2 process stations, we will collect particulate suspended matter using *in-situ* pumps from 6 different depths and at a maximum of 400 m. For this, we will deploy 6 *in-situ* pumps (e.g. McLane) equipped with two different filters types i.e., QMA filters with a nominal pore size of ~1 µm and a polyester pre-filter of 51 µm. Once the samples are back in the home laboratory, we will determine Hg, Methyl-Hg and carbon concentrations in the two grain fractions.

Further, at 4 stations, zooplankton (meso- and macrozooplankton) samples will be collected at 5 different depths. For mesozooplankton we will use a Multinet that will provide two different zooplankton sizes 55 µm and 200 µm. The macroozooplankton will be collected using RMT and IKMT nets. Once the samples are back in the lab in Germany, we will determine total Hg, Methyl-Hg and carbon and nitrogen concentrations.

**Preliminary (expected) results**

The expected data set will characterise 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 in the pelagic plankton community. Environmental transcriptomic and proteomic analyses will reveal the identities and metabolic strategies of plankton and enable the identification of dissolved extracellular proteins. 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.

**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). Environmental proteome data will be deposited in the publicly accessible Ocean Protein Portal (https://proteinportal.whoi.edu).

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 and Topic 6, Subtopic 3 and and additional funding by HGF/INSPIRES to project “Iron Impact”.

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# 5. CARBON DIOXIDE AND CARBONATE SYSTEM

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**Grant-No. AWI_PS133/1_05**

**Objectives**

The Southern Antarctic Circumpolar Current (S-ACC) contributes 40 % of the oceanic anthropogenic $CO_2$ sink. In the past, oceanic estimates of the Oceanic $CO_2$ sinks relied largely on simulations from coupled general circulation-biogeochemical and inverse models. The growing number in surface $CO_2$ measurements have recently allowed more detailed observation-based estimates of the oceanic carbon sink. Current estimates of carbon uptake and future predictions still suffer from large uncertainties due high interannual to decadal variability, lack of observations and wide range in model predictions, in particular in the southern high latitudes. Primary production in the area of study, fueled by the upwelling of nutrient rich circumpolar deep water, is largely limited by the availability of iron. Iron availability also critically influences plankton assemblage dynamics driving organic carbon but also nutrient export at depth. Measurements carried out in the Atlantic sector downstream of South Georgia indicate that this area might be one of the largest and most consistent carbon sinks in the S-ACC, most probably, due to the Island derived iron inputs fuelling higher productivity and carbon export at depth. Our first goal therefore is to improve carbon budget estimates during the growth season in the Atlantic sector of the S-ACC downstream of South Georgia from surface $fCO_2$ continuous measurements and seasonal biological C uptake and export from profile measurements of the carbonate system (DIC and total alkalinity) and standing stocks of particulate organic carbon. The combination of our measurements with detailed hydrographic data from the towed system (TRIAXUS) resolving the meso and sub-mesoscale will further allow to assess the importance of small scale physical processes in the carbon cycle as well as the importance of physical vs. biological processes driving carbon fluxes, sources and sinks in this region.

**Work at sea**

At all stations, water samples will be taken from the CTD rosette sampler at depths covering the whole water column. Total $CO_2$ (here referred to as DIC) and total alkalinity will be determined on board with a VINDTA instrument (MARIANDA, Kiel). DIC will be determined using a coulometric method. The accuracy will be set by internationally accepted and widely used certified reference material (CRM) obtained from Prof. A. Dickson at Scripps (USA). Total alkalinity measurements are carried out by potentiometric titration with a strong acid (HCl) using a high precision Metrohm Titrino for acid titration, a pH electrode and a reference electrode. Measurements will be carried out immediately after sampling. In cases were measurements cannot be carried out on board, samples will be preserved with mercuric chloride at 0.02 % final concentration and stored at 4° C for measurement in the home laboratory.

Surface water partial pressure of ($pCO_2$) will be collected from the ship's seawater supply continuously during the cruise using a General Oceanics system with a LiCOR infrared analyser both for seawater using a water-air equilibrator and for the atmosphere (pumped from the crow's nest).

### Preliminary (expected) results

Measurements of carbon dioxyde variables carried on board will provide information to estimate surface $CO_2$ air sea gas exchange in order to estimate the contribution of the Southern ACC to the carbon sources and sinks in the Atlantic sector of the Southern Ocean. Water column data will be used to estimate local and regional carbon budgets. In conjunction with the physical oceanography team we will further assess the impact of physical and biological processes at different scale (regional to the sub-mesoscale) on estimates of the Southern ACC carbon sink.

### 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) after data analysis and quality control. By default, the CC-BY license will be applied.

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

In all publications based on this expedition, the **Grant No. AWI_PS133/1_05** will be quoted and the following publication will be cited:

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# 6. NET COMMUNITY PRODUCTION

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Not on board: Klaus-Uwe Richter[1], Björn Rost[1]

**Grant-No. AWI_PS133/1_05**

## Objectives

One of the major open questions regarding the biogeochemistry of the Atlantic sector of the Southern Ocean is to which extent the micronutrient iron, leaking from the continental shelf around Southern Georgia, controls the primary productivity in this region.

The study region not only exhibits extensive primary production but also features the rapid transfer of carbon to higher trophic levels and considerable export fluxes to depth. The magnitude of these biogeochemical fluxes as well as their variability are uncertain.

Over the past 10 years, an extended mobile Membrane-Inlet Mass Spectrometer (MIMS) system has been developed in the section Marine Biogeosciences that can be deployed onboard research vessels to measure the concentrations of dissolved gases in the ship's seawater supply or in discrete bottle samples, e.g. derived from CTD casts. It has been previously tested on *Polarstern* expedition PS99a, and *Heincke* expedition HE519, and has successfully been deployed in the year-round MOSAiC drift study (Fig. 6.1) and the ATWAICE Cruise that explored (inter alia) the primary productivity of the Arctic marginal ice zone.

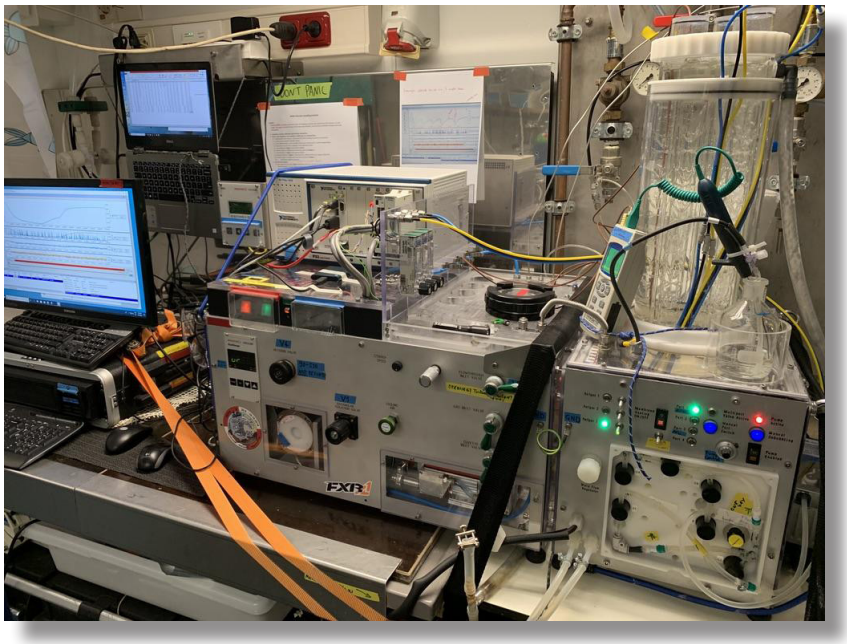

*Fig. 6.1: The ship-going MIMS system during the MOSAiC drift; photo credit: Emelia Chamberlain, Scripps*

### Work at sea

To better understand the magnitude as well as the spatial variability of biological activity and carbon fluxes, we will measure concentrations of dissolved $O_2$ and Ar underway in surface waters using membrane-inlet mass spectrometry (MIMS) to determine net community production in the study area (Craig and Hayward, 1987). Data will be combined with hydrological data (water mass identification), chemical data (nutrient fluxes, $CO_2$ concentrations), biological data (phytoplankton abundance, chlorophyll raw fluorescence), and meteorological data (wind speed) to derive estimates of net community production (Kaiser et al., 2005; Ulfsbo et al., 2014). Underway measurements will start shortly after the ship's departure from Cape Town (South Africa) and end before its arrival at port in Punta Arenas.

### Preliminary (expected) results

We will record a high-resolution dataset of $O_2$: Ar ratios in surface water that will be combined with the output from the ship's thermosalinograph to derive aequeous $O_2$ concentrations (Fig. 6.2). Published methods (Kaiser et al. 2005; Ulfsbo et al., 2014) will be used to estimate net community production or respiration, respectively. We expect that light regime, nutrient availability (especially iron) and grazing strongly modulate patterns of net community production and the subsequent carbon fluxes and potential sequestration. We will correlate our data with additional assessments of the mentioned parameters and attempt to quantify the contributions of such abiotic factors.

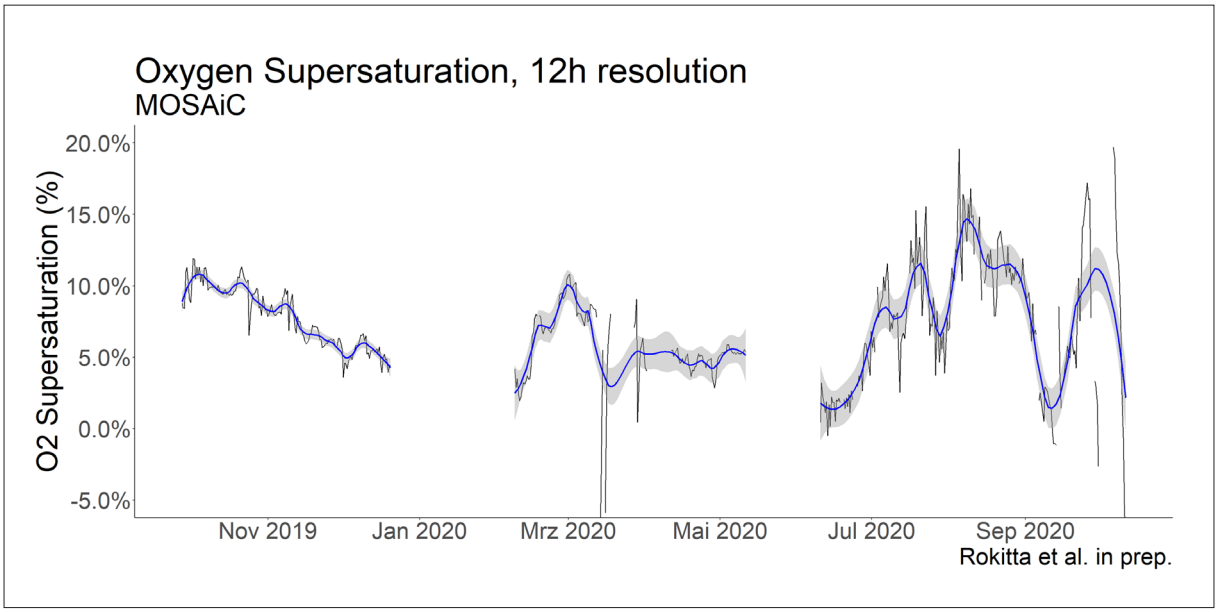


*Fig. 6.2: Oxygen saturation throughout the MOSAiC drift as an example of the anticipated underway data*

### Data management

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# 7. UNICELLULAR PLANKTON AND PARTICULATE MATTER

Christine Klaas[1], Clara Iachetti[2], Alexandra Kraberg[1], Leonard Rößler[3], Susanne Spahic[1], Jasmin Stimpfle [1], Dieter Wolf-Gladrow[1]; not on board: Irene Ruth Schloss[4], Rudolf Amann[3]

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**Grant-No. AWI_PS133/1_06**

## Objectives

Our aim is to determine how different environmental factors influence plankton assemblage composition and dynamics and the resulting impacts on biogeochemical fluxes. During PS133/1, in particular, we will investigate how differences in trace metal inputs (with increasing distance from South Georgia) versus other environmental parameters affect growth of key diatom and heterotrophic pro- and eukaryotes species, and the consequences for accumulation and export of organic matter and nutrients from the surface mixed layer. The study will combine sampling of surface waters for bulk particulate matter standing stocks and composition, microscopy and molecular analysis of plankton communities, incubation experiments to determine diatom species *in situ* growth rates and physiological status.

## Work at sea

*Suspended particulate matter*

Sampling and measurements of chlorophyll *a* (Chl *a*) will be carried out at discrete depths ranging from 5 to 250 m at all stations. Similarly, samples for particulate organic matter will be collected and filtered for analyses of particulate organic carbon and nitrogen (POC and PON) and biogenic silica (BSi) back in the home laboratory. Additional sampling in deeper layers (> 250 m) and underway (samples from the ship's moonpool) will expand the data range to be used for the calibration sensors (transmissometer and fluorometer) from the CTD-rosette and towed system (TRIAXUS). Water samples collected from Niskin bottles attached to a CTD-rosette (or moonpool) will be filtered onto 25 mm diameter GF/F filters at pressures not exceeding 200 mbar and processed for analysis of Chl*a* (on board). Filters for Chl*a* analysis will be immediately transferred to centrifuge tubes with 6 mL 90 % acetone and 1 ccm of glass beads. The sealed tubes will be stored at –20° C for at least 30 min and up to 24 hours. Chl*a* will be extracted by placing the centrifuge tubes in a grinder for 25 seconds followed by centrifugation at 0° C. The supernatant is poured in quartz tubes and measured for Chl*a* content in a calibrated Turner Trilogy fluorometer. Seawater (1 – 2 L and up to 10 L in deeper layers) samples for POC and PON analysis will be filtered onto pre-combusted 25 mm diameter GF/F filters and stored in pre-combusted glas Petri dishes. Filters will be dried overnight at 50° C and stored (–20° C) for further analysis on land. Seawater (2 L) samples for BSi analysis will be filtered onto polycarbonate filters (0.8 µm pore size) dried overnight at 50° C and stored in eppendorf tubes at –20° C for further analysis on land.

*Quantitative assessment of phyto- and heterotrophic assemblages*

Duplicate water samples for microscopic analysis of protist assemblages will be obtained from the CTD rosette at 8 discrete depths between 10 m and 200 m depth at each station. Samples

will be preserved with hexamine-buffered formalin solution (200 ml) and with Lugol's iodine (100 ml), respectively, at a final concentration of 2 % . Fixed samples will be stored at 4° C in the dark until counting back in the home laboratory. Hand net (20 µm mesh size) will be also used to collect plankton cells for more detailed taxonomic studies (SEM).

Further, samples for molecular analysis of the microbial communities will be collected to characterise assemblage diversity and compositon of protists and procaryotes (metagenomics, trancriptomics and fluorescent *in-situ* hybridisation) that cannot be identified using light microscopy. For the analysis of eukaryotic diversity, surface water samples will be collected with an automated sampler (AUTOFIM) stored at –80° C for later metabarcoding analysis. Samples for procaryotes diversity and metabolism will be collected at 3 discrete depths, filtered and stored at –80° C for later metagenomics analysis.

*In-situ diatom growth rates and physiological status*

Estimates of species-specific growth rates of diatom species will be obtained through incubation of undisturbed water samples under natural light and temperature conditions for up to 48 hours after staining with the fluorochrome PDMPO that binds to the newly deposited silica during cell division (Husmann and Klaas, 2022). The difference between *in-situ* growth rates determined with the PDMPO technique and the actual composition of diatom assemblages during this study will allow a quantitative estimate of the loss rates acting on individual species populations. Samples will be preserved with 2 % hexamine-buffered formalin and stored at 4° C for microscopy counts in the home laboratory. A Fast Repetition Rate Fluorometer (FRRF) (Chelsea Technology Group) will be used in a flow-through system to provide continuous surface measurement of phytoplankton photosynthetic performance (e.g. Fv/Fm), an indicator for iron limitation, during the entire cruise**.**

**Preliminary (expected) results**

The samples and results from the suspended matter analysis will provide basic information to understand the drivers and dynamics of the carbon and silicon cycles at large and small spatial and temporal scales. This information will complemented by our results on plankton abundances, composition and growth combined with data from other working groups on board, to understand factors driving phytoplankton species dynamics and processes (biological, chemical and physical) driving biogeochemical export fluxes in the open waters downstream of South Georgia. Finally, we will contribute to the study of how physical physical processes affect biogeochemical processes from the regional to the sub-mesoscale.

**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.

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# 8. MESOZOOPLANKTON

Jörg Dutz[1], Delove Asiedu[2], Jonas Bolduan[2]; [1]DE.IOW
not on board: Marja Koski[2] [2]DK.DTU

**Grant-No. AWI_PS133/1_07**

**Objectives**

Zooplankton is an integral part of the ocean's biological carbon pump. The efficiency of the biological pump is, among other things, dependent on the zooplankton community structure as well as the ecophysiology and behaviour of the species, all of which can have large regional variations. Large copepods effectively contribute to the vertical flux of organic material through repackaging of grazed primary production into large, fast sinking faecal pellets and wide diurnal migrations with respiration of ingested material at depth. The efficiency of the biological pump can, therefore, be related to their activity and stock size (Brun et al., 2019). Small copepods, however, may play a contrasting role and contribute to flux attenuation (Koski et al., 2020). Recent research demonstrates that they are far more abundant than previously thought and dominate the zooplankton abundance in many polar areas (Arendt et al., 2013). Species like *Oithona*, *Microsetella* or *Oncaea* are, furthermore, known to feed on sinking aggregates and faecal pellets and may by virtue of their large abundance have a large effect on the vertical flux.

Zooplankton community structure with regard to the contribution of large (> 1 mm) and small mesozooplankton (< 1 mm) is understudied in the Atlantic sector of the Antarctic Circumpolar Current (ACC). Studies conducted so far originate mainly from austral summer and have primarily used larger mesh sizes suitable to collect large zooplankton. These show a gradual change in the species composition across the zones of the ACC that is dominated by calanoid copepods such as Calanoides acutus, *Rhincalanus gigas* or *Metridia gerlachei* (e.g. Voronina 1998; Pakhomov et al., 2000, Ward et al., 2012). Few studies using smaller mesh size found that cyclopoid or poecilostomatoid copepods are equally abundant (Franzs and Gonzales 1997, Atkinson 1998). This is supported by observations in other areas around Antarctica. Typically, the abundance of zooplankton is larger north of South Georgia and downstream the ACC as well as at the Polar Frontal Zone (Franzs & Gonzales 1997, Atkinson 2001). The reasons are not well understood but may include accumulation of biomass by physical factors along convergence zones or enhanced production to due favourable food conditions (e.g. Krägefsky et al., 2009).

In contrast to other areas in the world ocean, a negative correlation between primary production and export flux in the Southern Ocean (Le Moigne et al., 2016) suggests that despite a high primary production a smaller fraction of the organic material sinks out of the euphotic zone. We hypothesise that a balance between stocks copepods that produce large sinking pellets (e.g., *Calanoides acutus*) and those that recycle particles (e.g., *Oncaea spp*.) may explain this pattern. We will test this along the productivity gradient from South Georgia and downstream along the flow of the ACC. Our key objectives are to:

- Investigate the change in community composition of the mesozooplankton along a latitudinal gradient with regard to size structure and functional types.

- Estimate the importance of large vs. small copepods to export production, by comparing their stock sizes and their production (as faecal pellet production) and degradation (feeding) of sinking particles.
- Understand the effect of environmental conditions (temperature, food availability) on the production of key players in both size groups.

### Work at sea

The community composition, abundance, vertical distribution and population structure of small (< 1 mm) and large mesozooplankton (> 1 mm) will be studied from vertical tows of MultiNets equipped with 55 and 150 µm mesh size, respectively. Vertical tows will be done from a depth of 600 m to the surface at five depth intervals: 600–200 m, 200–100 m, 100–50 m, 50–25 m, 25–0 m. In addition, the diurnal vertical migration within the community will be investigated at the longer process stations through day and night MultiNet tows. Gut fluorescence measurements and gut evacuation rates will be measured to inform on the degree of herbivory of the dominating species as well as to give an estimate of the feeding rates. Incubations (24 hours) will be carried out to determine faecal pellet and egg production rates as well as egg hatching success of selected key species within the large copepod species. Egg production rates of smaller copepods will be based on the egg ratio method using the 55 µm MultiNet samples. Finally, degradation rates of faecal pellets or other sinking particles by dominant small copepod species will be measured in additional incubations.

### Preliminary (expected) results

The results will describe the change in the taxonomic and functional diversity of zooplankton in the area related to differences in hydrography and productivity. Faecal pellet production and degradation estimates will be combined with the stock estimates of large and small copepods in order to establish their relative importance to export flux. These results will be compared to estimates of vertical flux determined from sediment traps. Finally, we expect new knowledge on the contribution of small and large copepods on *in situ* secondary production in the area.

### 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.

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.

In all publications based on this expedition, the **Grant No. AWI_PS133/1_07** 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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# 9. MACROZOOPLANKTON AND MICRONEKTON ECOLOGY

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**Grant-No. AWI_PS133/1_08**

**Objectives**

Large zooplankton and micronekton are a cornerstone of the biological pump occupying an important intermediate position between primary producers and secondary consumers. Their role in the ocean is multifaceted as zooplankton and micronekton acts as a “gatekeeper” for the carbon leaving the euphotic zone into the mesopelagic realm. Aggregation of particles, grazing, active vertical migrations, nutrient and iron release during feeding are all critically important in the dynamics of the organic matter vertical flux in the ocean. The length of the individual food chains will determine the productivity at the upper trophic levels as well as the degree of retention and/or sedimentation of the organic matter out of the euphotic zone of the ocean. Recently, much effort has been directed to understand factors controlling the transformation of organic matter in the ocean. The “Island Impact” cruise will provide a unique opportunity to study the zooplankton dynamics, with a particular emphasis to microzooplankton and micronekton, across various oceanographic regimes. One of the target species during the voyage will be pelagic tunicates, *Salpa thompsoni*, that are numerous in the region investigated. This species is instrumental in shaping plankton communities and contributes significantly to the Southern Ocean biological pump. Moreover, the tunicate contribution to carbon flux may be altered due to climate change.

The main objectives are to focus on the characterisation of microzooplankton and micronekton, with the focus on pelagic tunicate *S. thompsoni* population dynamics, to assess their contribution to total zooplankton standing stock and estimate their contribution to carbon flux. It is envisaged that our objectives will intertwine closely with the objectives of the other research groups.

The main aims during the voyage will be:

- to measure the composition, size structure and standing stock (abundance and biomass) of macrozooplankton and micronekton;
- to study pelagic tunicate, *Salpa thompsoni*, horizontal and vertical distribution, density, developmental composition, population biology and feeding ecophysiology;
- to collect form, stage and size specific data on the vertical distribution of *S. thompsoni* (jointly with the “Marine particles and aggregates” group);
- to assess the contribution of selected taxonomic groups to passive and active carbon transport (jointly with the “Mesozooplankton” and “Marine particles and vertcal fluxes” groups);
- to obtain material for subsequent stochiometric and genetic work for gelatinous (jellyfish, ctenophores and tunicates) zooplankton.

**Work at sea**

Our minimum sampling efforts will concentrate along all five transects with IKMT (Isaacs Kidd Midwater Trawl, 2.5 $m^2$ mouth area, 0.505 mm mesh) deployments obliquely down to 200 m depth at a spatial resolution of 60 nmi. At the longer "process stations", both IKMT and RMT-8 (Rectangular Midwater Trawl, mouth area 8 $m^2$, 4.5 mm mesh size) trawls will be deployed during the daytime and night-time obliquely down to 200 m and 600 m depth, respectively. Occasional (time permitting) shallow (0 – 50 m) IKMT trawls may be carried out to obtain specimens for experiments. It is envisaged that both IKMT and RMT-8 samples will be processed for taxonomy, size and abundance on board and only selected specimens will be fixed in the formalin solution for subsequent morphological analysis and ID confirmation. In addition, salp specimens will be collected for transcriptomic studies (frozen in –80° C) and selected jellyfish and ctenophore species will be frozen at –20° C for the subsequent laboratory stochiometric analyses.

Pelagic tunicates (all salps or subsamples in large catches) will be counted, measured and analysed for the biology (form, sex, size, developmental stage). A representative sample of salp stomachs will be extracted and placed into 90 % acetone to obtain gut pigment content of salps needed to assess their grazing impact. In addition, freshly caught and healthy salps will be used for gut evacuation as well as for faecal pellet production experiments in the temperature-controlled containers. Freshly produced faecal pellets will be collected in Eppendorf tubes and frozen at –80° C for subsequent C/N and pigment content as well as for genetic analyses. Salp diel vertical migrations will be studied using the underwater camera mounted on the particle profiler (joint project with the "Marine particles and sinking fluxes" group) at the "process stations". The profiler will be deployed during the day- and nighttime to a depth of 800 m. Preliminary imaging will be completed at sea and vertical distribution of main macroplanktonic and micronektonic organisms will be compared to the multi-frequency SIMRAD data.

**Preliminary (expected) results**

The collected data set will provide a comprehensive description and density assessment of the macrozooplankton and micronekton community in the waters downstream of South Georgia using net, acoustic and underwater camera sampling. This would allow describing taxonomic and functional diversity of macroplankton/micronekton in various oceanographic regimes. In particular, for most abundant species of interest, salps and hyperiids, the biological development will be assessed. Density data would allow to estimate the grazing impact of herbivorous metazoans, salps in particular. Faecal pellet production experiments will assess the salp contribution to the export flux. Underwater camera and acoustic sampling will provide active carbon transport estimates. Stoichiometric and elemental composition data on gelatinous functional group would allow placing quantitatively of this group into biochemical models. Full size stricture of the plankton community, obtained in collaboration with mesozooplankton and the marine flux groups, will lead to better understanding of remineralization processes and quantification of the microbes, zooplankton and micronekton roles in the vertical carbon flux.

**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.

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

In all publications based on this expedition, the Grant No. AWI_PS133/1_08 will be quoted and the following publication will be cited:

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# 10. MARINE PARTICLES AND SINKING FLUXES

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**Grant-No. AWI_PS133/1_09**

## 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 PS133/1 “Island Impact” study. During the voyage we will focus on

- Measuring particle (plankton and aggregates) distribution and composition in the water column.
- Measure 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.

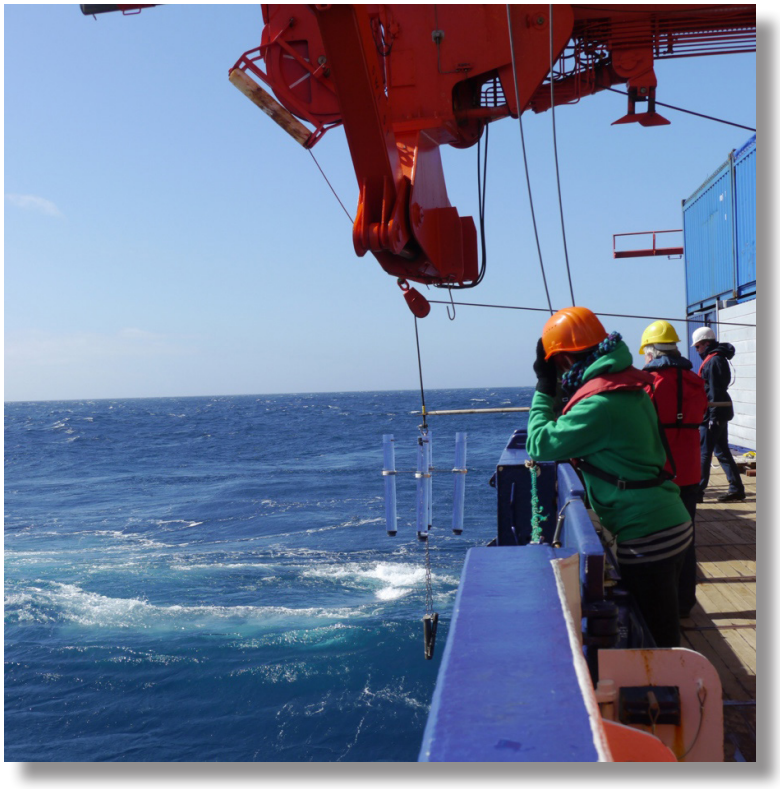

*Fig.10.1: Deployment of a free drifting sediment trap station*

**Work at sea**

Particle characteristic (size, shape 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 a coupled CTD and underwater camera systems to allow quantification of the whole size spectrum including the larger macrozooplankton and aggregates (ROSINA and SalpCam).

During the process stations, export fluxes will be collected below the mixed layer and permanent thermocline (~100 and ~400 m depth, respectively) using a free drifting array with two sediment trap stations (KC denmark) consisting of four cylindrical sinking matter collectors each (Fig. 10.1). Material from three collectors at each depth level will be used for biogeochemical analyses, 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. These will be digitally analysed on board.

At the process stations a large volume sampler, the Marine Snow Catchers (MSC), will be used to collect *in situ* formed marine snow and other particles. The MSC consisted of a 100 L cylindrical water sampler with a particle collection tray at the bottom deployed with a winch to the target depth and closed via a release mechanism. The closed MSC will be placed on deck for a few hours to allow the collected particles to sink into the collection tray. After gently draining the water from the 100 L cylinder, the collection tray containing the settling particles will be used to determine the collected aggregates, 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 and at anoxic conditions. Similar measurements on zooplankton faecal pellets both from water column and incubations (collaboration with mesozooplankton and macrozooplankton groups) will be carried out.

**Preliminary (expected) results**

The expected data set will determine vertical distribution of aggregates and zooplankton as well as biogeochemical export fluxes in the open waters downstream of South Georgia. 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 remineralisation 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 zooplankton and trace metal groups on board during PS133/1.

**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.

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 and Topic 6, Subtopic 3.

In all publications based on this expedition, the **Grant No. AWI_PS133/1_09** will be quoted and the following publication will be cited:

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# 11. PHYTOOPTICS

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**Grant-No. AWI_PS133/1_11**

## Outline

Marine phytoplankton is the basis of the marine food web and also a main component of biogeochemical fluxes, thus, an important source of dissolved and particulate organic substances, including volatile organic substances (e.g. DMS, isoprene, halocarbons). The contribution of the Phytooptics group during this cruise leg is the measurements of biooptical properties and pigment composition, as well measuring continuously at the surface water but also at discrete CTD and associated light stations, and during the Top-AWI operation in the water profile (down to max. 120 m). The main focus is to process these different optical datasets by verification with phytoplankton group data derived from collocated HPLC measurements to determine the amount and composition of phytoplankton throughout the water column along the cruise transect. In addition, the absorption by other particles and coloured dissolved organic matter (CDOM), the reflectance and diffuse attenuation of the underwater light from the UV to the NIR are determined. The data sets will be used to validate ocean colour retrievals and data products from the two Copernicus satellite missions Sentinel-3 and 5, but also to upscale information of these components via the complementation to satellite and previous field data acquisition for the analysis of long-term trends of these parameters in the South Atlantic region (Bracher, 1999; Bracher et al., 1999; Soppa et al., 2013; Soppa et al., 2014; Soppa et al., 2016; Cheah et al., 2017; Bracher et al., 2020).

## Objectives

During PS133/1 our objectives are to:

- collect data sets on phytoplankton (total and composition) and its degradation products at the surface and for the full euphotic zone using continuous optical observations during the cruise and from ocean colour remote sensing calibrated with discrete water sample measurements,
- develop and validate (global and regional) algorithms and associated radiative transfer models in accordance to the previous objective by using discrete water samples for pigment analysis and absorption measurement,
- obtain a big data set for ground-truthing ocean color satellite data, specifically from the new Sentinel-3 (A and B) OLCI and the Sentinel-5-Precursor TROPOMI sensors,
- support the optical data collection by the Top-AWI-Triaxus towed system via instrument calibration, monitoring and comparisons to our underway and station optical data collection,
- obtain a spectral characterisation of the underwater light field and its interplay with optical constituents, such as phytoplankton and CDOM abundance and composition.

**Work at sea**

During PS133/1, continuous measurements with optical sensors will be taken from surface waters and within the euphotic zone of the water column from the TRIAXUS transects and at discrete stations with the light profiler. Collocated data to ocean color sensors OLCI data (launched in February 2016 and April 2018, respectively, on Sentinel-3A and -3B) will be acquired for validation at as many locations as possible (the Phytooptics groups is within the Sentinel-3 Validation team). These *in-situ* data are important also for the validation of the group's own satellite products (e.g., Oelker et al., 2022; Xi et al., 2021; Bracher et al., 2009) on phytoplankton composition and its distribution. The continuous biooptical data will be regularly calibrated with measurements at discrete water samples determining the phytoplankton pigment composition using the HPLC method and the optical properties using spectrophotometric instrumentation.

Active and passive bio-optical measurements for the survey of the underwater light field, specific light attenuation, particle and phytoplankton composition and distribution shall be performed continuously on the surface water but also whithin the euphotic layer during the TRIAXUS operations and daily noon-time CTD stations:

For the continuous underway surface sampling an *in-situ* spectrophotometer (ACS; Wetlabs) will be operated in flow-through mode to obtain total and particulate matter attenuation and absorption of surface water. The instrument is mounted to a seawater supply taking surface ocean water. A flow-control with a time-programmed filter is mounted to the ACS to allow alternating measurements of the total and the CDOM inherent optical properties of the seawater. Flow-control and debubbler-system ensure water flow through the instrument with no air bubbles.

A second ACS instrument is mounted on a steel frame together with a depth sensor and a set of hyperspectral radiometers (Ramses sensors from TRIOS) and operated during CTD stations around noon time daily. The frame is lowered down to maximal 120 m with a continuous speed of 0.1 m/s or during daylight with additionally stops at 2, 4, 6, 8, 10, 12.5, 15, 20, 25 and 30 m to allow a better collection of radiometric data. The Apparent Optical Properties of water (AOPs) (surface reflectance and light attenuation through the water column) will be estimated based on downwelling and upwelling irradiance measurements in the surface water profile (down to the 0.1 % light depth) from the radiometers calibrated for the incident sunlight with measurements of a radiometer on deck. The ACS will measure the inherent optical properties (IOPs: total attenuation, scattering and absorption) in the water profile.

Discrete measurements of IOPs (absorption) at water samples will be performed 1) On samples from the underway surface sampling (as for the ACS flow-through system at from the ship's seawater pump) at an interval of 3 hours, 2) On samples from the station at 6 depths within the top 100 m collected with the CTD-rosette verical profiles. Water samples for CDOM absorption analysis are filtered through 0.2 µm filters and analysed onboard with a 2.5-m path length liquid waveguide capillary cell system (LWCC, WPI) following Levering et al. (2017). Particulate and phytoplankton absorption coefficients are determined with the quantitative filter techniques using sample filtered onto glass-fiber filters QFT-ICAM and measuring them in a portable QFT integrating cavity setup Röttgers et al. (2016).

Samples for determination of phytoplankton pigment concentrations and composition are taken at a 3-hourly interval from the underway-sampling system, and from 6 depths (max. 100 m) at CTD-stations. These water samples are filtered on board immediately after sampling and the filters are thermally shocked in liquid nitrogen. Samples are stored at –80°C until ship is back in Bremerhaven and then will be analysed within the next three months by High Performance Liquid Chromatography Technique (HPLC) at AWI following Taylor et al. (2011) adapted to our new instrumentation as described in Alvarez et al. (2022).

The acquisition of optical data (hyperspectral AOPs from three RAMSES sensors, hyperspectral IOPs from a third ACS instrument, Chlorophyll and CDOM fluorescence and backscatter at 550 nm from a wetlabs triplet sensor, and overall visible light from a PAR sensor) during the TRIAXUS surveys will be supported by calibration of the instruments and later analysis of the data. The measurements of the ACS run continuously on board and in the water column at stations will be compared to the ACS run on the Top-AWI/TRIAXUS system to ensure quality control for the Top-AWI-ACs system. In addition the discrete measurements on water samples will be used to calibrate the above mentioned TRIAXUS sensor data.

### Preliminary (expected) results

Discrete water measurements of particle, phytoplankton and CDOM absorption will be analysed on board. Back in the home laboratory, phytoplankton pigment composition and concentration will be determined and sensor data will be further processed to obtain quality control hyperspectral particulate and CDOM absorption, reflectance, diffuse attenuation and transmission data. Semi-analytical techniques will be used to determine the spectrally resolved underwater light attenuation and the distribution of phytoplankton total and groups and their biomass, CDOM and non-algal particles.

Finally, the products on phytoplankton groups developed from the various hyperspectral optical sensors used on different platforms during the expedition together with the S3 global products shall be integrated via data fusion with these satellite products to produce for the time frame and area of PS133-1 expedition a four dimensional data set (of about 3–5 days in temporal, 500 m in spatial and 10 m in vertical resolution) enabling the upscaling of the the detailed station based observations on primary productivity and biogeochemical cycling from this expedition. This work is integrated into the PhD thesis of participant Ehsan Mehdipour funded by MARDATA and Inspire via the project “4D-Phyto” (see project sketch in Fig. 11.1).

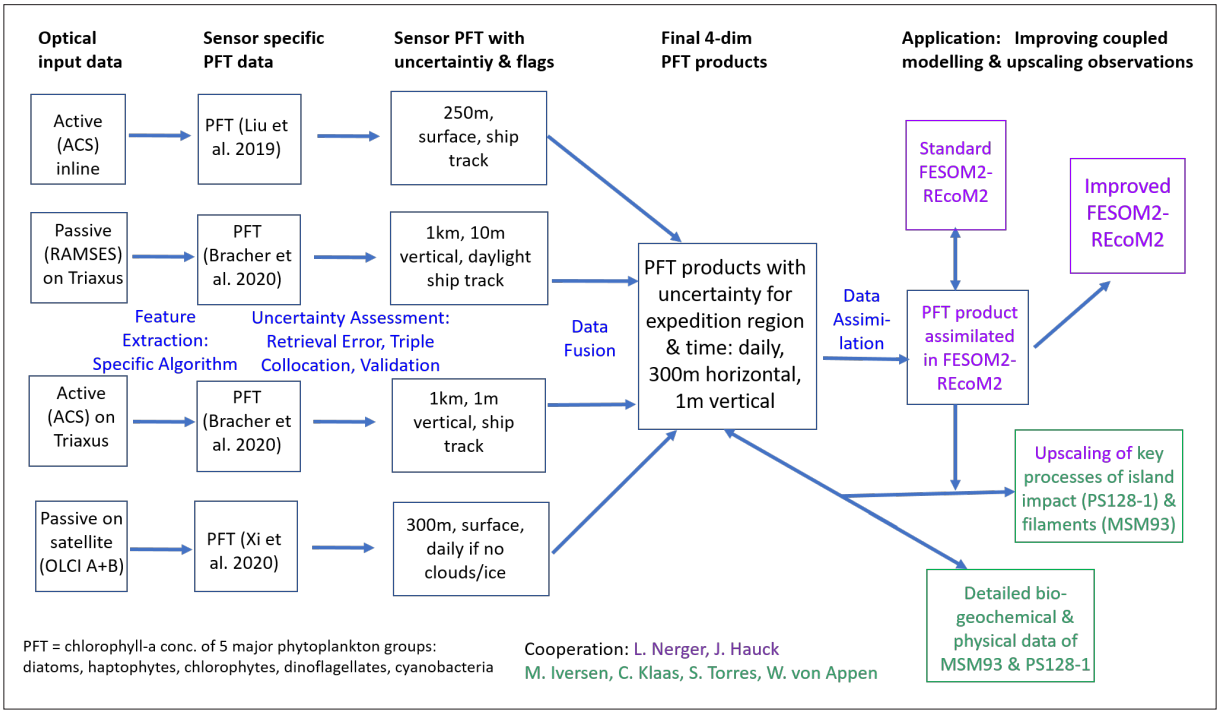


*Fig. 11.1: Work-flow of the integration of PS133-1 optical sensor with satellite data information on phytoplankton groups' biomass as planned within the MARDATA-inspire Project D-Phyto*

## Data management

The quality controlled optical and pigment samples during this expedition and the derived geophysical quantities 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.

This expedition was supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 6, Subtopic 3 and additional funding by HGF/MARDATA to project “4D Phyto”.

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# 12. SEDIMENT BIOGEOCHEMISTRY

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**Grant-No. AWI_PS133/1_10**

## Outline

The amount of organic material that escapes mineralisation and is retained in the sediment record is the single most important factor determining the $O_2$ levels of the global ocean. Today we have a reasonably good understanding of the processes that are responsible for the mineralisation of organic material. But many areas of the deep sea – in particular trenches with unique deposition dynamics – are still poorly explored. The Atlantic sector of the Southern Ocean, including the South Sandwich Trench, encompasses some of the most productive marine regions and is characterized by an efficient biological pump carrying large quantities of organic carbon to deep-sea sediments. Trenches only account for less than 2% of the global seabed area, but could via sediment focusing act as regionally important but unexplored traps for organic material. Benthic mineralisation is mainly driven by vast numbers of Bacteria and Archaea. Currently even the most basic information on abundance and distribution of microbes in deep sea and trench sediments are missing. We want to quantify the carbon mineralisation-efficiency of bathyal, abyssal and hadal sediments in the Southern Ocean, identify the key players for the processing and and compare rates and communities with other deep sea and trench ecosystems.

## Objectives

The proposed work will target 10 stations with variable surface production covering a depth range of 2 to 8.2 km in the Southern Polar Ocean and South Sandwich Trench system. The specific research aims include:

*Quantification of the pelagic export and benthic mineralisation of organic carbon*

Using state-of-the-art lander technology, we will measure *in situ* benthic oxygen consumption rates within and around the South Sandwich Trench. The data will provide a unique assessment of the regional benthic carbon mineralisation rate and fill data gaps in the current global data base. The involved diagenetic pathways will be quantified from porewater profiles and the distribution of solid-state iron and mangenase and onboard measurements of sulfatereduction. The site-specific turn-over rates will be linked to the pelagic activity and sedimentation rates derived form the distribution of natural radio nucleides, but will also be linked to long term assessments of pelagic productivity at the respective sites estimated from remote sensing (Wenzhöfer and Glud 2002; Jørgensen et al., 2022). Thereby we will assess the quantitative link between surface production and underlying benthic activity, and evaluate the potential importance of horizontal transport of organic material in the complex benthic seascape of the region.

*Characterisation of the quantity and quality of deposited organic material*

Recovered sediment cores will be used to assess the source, quantity and quality of organic material deposited at the respective sites. Beside basic quantification of total organic carbon (TOC), the analyses will include detailed pyrolysis for assessing lability, stable isotopes ($\delta^{13}C$, $\delta^{15}N$ signatures), phytodetrital pigments and biomarker investigations using procedures that we have applied in other marine and hadal settings.

*Exploring benthic communities (viral, prokaryotes, and meiofaunal communities) in relation to ocean depth and food supply*

We will analyse the phylogenetic composition of the microbial communities through next-generation sequencing (metagenomics and amplicom sequencing). Microbes and DNA will be extracted from recovered cores applying procedures we have used in other deep sea and hadal settings. The resolved community compositioned will be linked to the zonation of the respective diagenetic pathways to explore sucession and evoloution of key players involved in benthic mineralisation at the respective site.

*Exploring the biogeochemical function and community composition of the hadal realm*

The proposed study is essential for understanding carbon cycling, pelagic-benthic coupling and benthic community structures in this very important region of the Southern Ocean. However, the work should also be seen in the context of a wider ambition of exploring life and biogeochemical function of hadal trenches. The proposed work in the productive region of the South Sandwich Trench system will greatly complement investigations on hadal systems of different biogeographic provinces. The combined data will provide generic insights on the biogeochemical function and life in hadal trench systems underlying different productivity regimes. The analysis on community structures will explore the extent by which trench systems act as isolated biogeographic habitats dominated by unique co-evolving communities or if they represent interconnected extreme environments.

**Work at sea**

We plan to address ecosystem functions such as benthic respiration, remineralisation and matter transport, microbial and meiofauna biodiversity in the South Sandwich Trench and adjacent abyssal and bathyal sediments of the Southern Ocean. During the proposed work programme, we will investigate 3–4 trench sites (>6,000 m) and 7 sites at a depth ranging from 5,000 to 2,000 m. The main focus will be on *in situ* benthic flux rate measurements and sediment sampling. Measurements will be added to the existing scarce data base of deep sea and hadal data. We will perform *in situ* measurements using a new Hadal-benthic Flux Lander (11,000 m) to study benthic oxygen uptake and fluxes of other solutes at the sediment water interface (Wenzhöfer and Glud, 2002; Glud et al., 2013). The Lander is equipped with two benthic chambers and a 2-axis microprofiler. The benthic chambers are used to measure total exchange rates of the sediment integrating all relevant solute transport processes (diffusion, advection and fauna-mediated transport) and an area of 400 $cm^2$. During the deployment an oxygen optode measures changes in the oxygen concentration of the enclosed overlying water (total oxygen uptake, TOU) and 7 syringes take water samples at pre-programmed time intervals for analyses of DIC and nutrients. Furthermore, the enclosed sediments are retrieved and sampled on board for total organic carbon (TOC) and photopigment content as well as for abundances of microorganisms and fauna. The X-Y microprofiler will be used to perform multiple vertical oxygen profiles across the sediment-water interface. It is equipped with up to 9 $O_2$ electrodes, 1 conductivity sensor and 1 temperature sensor capable to perform multiple vertical sets of concentration profiles along a horizontal distance of 50 cm. Measurements across the water-sediment interface and within the upper sediment layer will be performed

with a vertical resolution of 100 µm and extending over a total length of 15–25 cm. The X-Y microprofiler will be used to quantify the diffusive oxygen uptake (DOU), which is generally assigned to microbial respiration.

A multiple corer (MUC) will be used, in order to retrieve undisturbed sediment samples. Sediments will be analysed for various biogenic sediment compounds indicating the input of organic matter to the seafloor as well as the activity and biomass of the small sediment-inhabiting biota. Due to the limited number of personnel on board sediment cores will be sectioned (1 cm slices to 10 cm, then in 2 cm slices to 20 cm and then in 5 cm slices to the bottom of the core) and samples stored according to the analyses performed later in the home laboratory.

### Preliminary (expected) results

The result will add to our growing database on microbial carbon mineralisation in deep sea (Jørgensen et al., 2022) and hadal settings (Glud et al., 2021; Wenzhöfer et al., 2016) and allow for comparison between hadal environments experiencing different regimes of vertical carbon export. Additionally, a multidisciplinary and quantitative approach will be applied to explore the connection, composition and structure of benthic communities in the deepest area of the mesotrophic Southern Ocean using up-to-date methods and technologies. The insight will be compared with similar investigations that we have conducted in the eutrophic Atacama Trench and oligotrophic Kermadec Trench region. This will provide a generic insight on biogeochemical function and community compositions in hadal trench and deep searegions.

### 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.

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In all publications based on this expedition, the **Grant No. AWI_PS133/1_10** 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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Glud RN, Berg P, Thamdrup B, Larsen M, Stewart HA, Jamieson AJ, Glud A, Oguri K, Sanei H, Rowden AA, Wenzhöfer F (2021) Hadal trenches are dynamic hotspots for early diagenesis in the deep-sea. Commun Earth Environ 2:21; https://doi.org/10.1038/s43247-020-00087-2

Glud RN, Wenzhöfer F, Middelboe M, Oguri K, Turnewitsch R, Canfield DE, Kitazato H (2013) High rates of benthic microbial activity at 10.900 meters depth: Results from the Challenger Deep (Mariana Trench), Nature Geoscience 6:284-288. https://doi.org/10.1038/NGEO1773

Jørgensen BB, Wenzhöfer F, Egger M, Glud RN (2022) Sediment oxygen consumption: Role in the global marine carbon cycle. Earth-Science Reviews 228:103987. https://doi.org/10.1016/j.earscirev.2022.103987

Wenzhöfer F, Oguri K, Middelboe M, Turnewitsch R, Toyofuku T, Kitazato H, Glud RN (2016) Benthic carbon mineralisationin hadal trenches: Assessment by *in situ* O2 microprofile measurements. Deep Sea Res I, 116:276-286.

# 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

| Affiliation | Institute |
|---|---|
| AR.IAA | Instituto Antártico Argentino<br>25 de Mayo 1143<br>San Martín<br>Provincia de Buenos Aires<br>Argentina |
| AR.CADIC | Centro Austral de Investigaciones Cientificas<br>Bernardo Houssay 200<br>9410 Ushuaia<br>Argentina |
| BR.UFRG | Universidade Federal do Rio Grande<br>Av. Itália, Km 8<br>LEOC<br>96203900 Rio Grande<br>Brazil |
| CA.DAL | Dalhousie University<br>1355 OXFORD ST<br>PO Box 15000<br>B3H 4R2 Halifax<br>Canada |
| CA.OFI | Ocen Frontier Institute<br>Steele Ocean Sciences Building<br>1355 Oxford Street<br>Halifax, NS B3H 3Z1<br>Canada |
| CA.UBC | University of British Columbia<br>2020 – 2207 Main Mall<br>V6T 1Z4 Vancouver<br>Canada |
| DE.AWI | Alfred-Wegener-Institut<br>Helmholtz-Zentrum für Polar- und Meeresforschung<br>Postfach 120161<br>27515 Bremerhaven<br>Germany |

| Affiliation | Institute |
|---|---|
| DE.DRF | DRF Luftrettung gAG<br>77836 Rheinmünster<br>Germany |
| DE.DWD | Deutscher Wetterdienst<br>Seewetteramt<br>Bernhard Nocht Str. 76<br>20359 Hamburg<br>Germany |
| DE.GEOMAR | GEOMAR Helmholtz-Zentrum für Ozeanforschung<br>Wischhofstraße 1-3<br>24148 Kiel<br>Germany |
| DE.IOW | Leibnitz-Institut für Ostseeforschung<br>Seestraße 15<br>18119 Rostock-Warnemünde<br>Germany |
| DE.JU | Jacobs University Bremen<br>Campus Ring 1<br>28759 Bremen<br>Germany |
| DE.MARUM | MARUM – Zentrum für Marine Umweltwissenschaften<br>der Universität Bremen<br>Leobener Str. 8<br>28359 Bremen<br>Germany |
| DE.MPIMM | Max Planck Institute for Marine Microbiology<br>Celsiusstraße 1<br>28359 Bremen<br>Germany |
| DE.NHC | Northern HeliCopter GmbH<br>Gorch-Fock-Straße 103<br>26721 Emden<br>Germany |
| DE.TU-Braunschweig | Technische Universität Braunschweig<br>Langer Kamp 19C<br>Raum 303C<br>38106 Braunschweig<br>Germany |

| Affiliation | Institute |
|---|---|
| DE.UNI-Bremen | Bremen University<br>Institut für Umweltphysik<br>Otto-Hahn-Allee 1<br>28359 Bremen,<br>Germany |
| DE.UNI-Hamburg | Universität Hamburg<br>Mittelweg 177<br>20148 Hamburg |
| DE.UNI-Heidelberg | Universität Heidelberg<br>Grabengasse 1<br>69117 Heidelberg<br>Germany |
| DE.UNI-Köln | University of Cologne<br>Zülpicher Strasse 49b<br>50764 Köln<br>Germany |
| DK.SDU | University of Southern Denmark<br>Campusvej 55<br>5230 Odense<br>Denmark |
| DK.DTU | Technical University of Denmark<br>National Institute of Aquatic Resources<br>Kemitorvet<br>Building 202<br>2800 Kgs. Lyngby<br>Denmark |
| EDU.Caltech | California Institute of Technology<br>1200 East California Boulevard<br>91125 Pasadena CA<br>United States |
| EDU.UCSD | University of California San Diego<br>Scripps Institution of Oceanography<br>9500 Gilman Drive<br>92093 La Jolla CA<br>United States |

| Affiliation | Institute |
|---|---|
| UERJ | Universidade do Estado do Rio de Janeiro<br>R. São Francisco Xavier 524 –<br>Campus Maracanã<br>sala 4008 bloco E<br>20550-900 Rio de Janeiro<br>Brazil |
| US.WHO | Woods Hole Oceanographic Institution<br>266 Woods Hole Road<br>Woods Hole MA 02543-1050<br>USA |

## A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

| Name/ Last name | Vorname/ First name | Institut/ Institute | Beruf/ Profession | Fachrichtung/ Discipline |
|---|---|---|---|---|
| Asiedu | Delove | DK.DTU | PhD student | Oceanography |
| Bahl | Alexis | CA.UBC | PhD student | Oceanography |
| Becker | Hauke | DE.AWI | Engineer | Oceanography |
| Bolduan | Jonas | DK.DTU | PhD student | Oceanography |
| Bracher | Astrid | DE.AWI<br>DE.UNI-Bremen | Scientist | Oceanography |
| Cotrim da Cunha | Leticia | UERJ | Scientist | Chemistry |
| Da Conceição Dos Santos | Raquel Avelina | UERJ | PhD student | Oceanography |
| Dove | Lilian | EDU.Caltech | Student | Oceanography |
| Dutz | Jörg | DE.IOW | Scientist | Biology |
| Ebner | Berenice | DE.AWI | PhD student | Geology |
| Eckardt | Lorenz | DE.AWI | Technician | Biology |
| Gischler | Michael | DE.NHC | Pilot | Helicopter service |
| Glud | Anni | DK.SDU | Technician | Biology |
| Glud | Ronnie | DK.SDU | Scientist | Biology |
| Hölemann | Anna | DE.AWI | Student | Oceanography |
| Hölemann | Jens | DE.AWI | Scientist | Oceanography |
| Hübner | Joshua | DE.AWI | Student | Chemistry |
| Iachetti | Clara | AR.CADIC | Scientist | Biology |
| Iversen | Morten | DE.AWI | Scientist | Biology |
| Klaas | Christine | DE.AWI | Scientist | Biology |
| Konrad | Christian | DE.AWI | Engineer | Biology |
| Kraberg | Alexandra | DE.AWI | Scientist | Biology |
| Ludwichowski | Kai-Uwe | DE.AWI | Engineer | Chemistry |
| Lüskow | Florian | CA.UBC | PhD student | Biology |
| Marquez Orselli | Iole Beatrix | BR.UFRG | Scientist | Oceanography |
| Marchant | Hannah | DE.MARUM | Scientist | Biogeochemistry |
| McQuaid | Jeff | EDU.UCSD | Scientist | Biology |
| Marques Orselli | Iole Beatriz | BR.UFRG | Scientist | Oceanography |
| Mehdipour | Ehsan | DE.AWI<br>DE.JU | PhD student | Oceanography |
| Mole | Ryan | DE.AWI | PhD student | Oceanography |
| Nordhausen | Axel | DE.MPIMM | Technician | Engineering |
| Oetjens | Annika | DE.AWI<br>DE.UNI-Heidelberg | Student | Physics |
| Otte | Frank | DE.DWD | Scientist | Meteorology |
| Pakhomov | Evgeny | CA.UBC | Scientist | Biology |
| Pakhomova | Larysa | CA.UBC | Technician | Oceanography |

| Name/ Last name | Vorname/ First name | Institut/ Institute | Beruf/ Profession | Fachrichtung/ Discipline |
|---|---|---|---|---|
| Panter | Gabriel | DE.DRF | Technician | Helicopter service |
| Pattison | Larissa | CA.DAL | Technician | Biology |
| Perez-Rodriguez | Marta | DE.TU-Braunschweig | Scientist | Geochemistry |
| Rokitta | Sebastian | DE.AWI | Scientist | Biology |
| Rössler | Leonard | DE.MPIMM | Student | Biology |
| Schaubensteiner | Stefan | DE.NHC | Pilot | Helicopter service |
| Spahic | Susanne | DE.AWI | Technician | Biology |
| Stimac | Ingrid | DE.AWI | Technician | Chemistry |
| Stimpfle | Jasmin | DE.AWI | PhD student | Biology |
| Stöckle | Sonja | DE.DWD | Scientist | Meteorology |
| Terbruggen | Anja | DE.AWI | Engineer | Biology |
| Trimborn | Scarlett | DE.AWI | Scientist | Biology |
| Völkner | Christian | DE.AWI | Engineer | Biology |
| von Appen | Wilken-Jon | DE.AWI | Scientist | Oceanography |
| Wenzhöffer | Frank | DE.AWI | Scientist | Biology |
| Wolf-Gladrow | Dieter | DE.AWI | Scientist | Physics |
| Woll | Matthias | DE.AWI | Engineer | Chemistry |
| Zitoun | Rebecca | DE.GEOMAR | Scientist | Chemistry |

## A.3 SCHIFFSBESATZUNG / SHIP'S CREW

| Name | Vorname | Master |
|---|---|---|
| Schwarze | Stefan | Mate |
| Kentges | Felix | Chiefmate |
| Hering | Igor | 2nd Mate |
| Grafe | Jens | Chief |
| Lange | Felix | 2nd Mate |
| Falk | Stefan | 2nd Mate |
| Müller | Andreas | ELO |
| Goessmann - Lange | Petra | Shops Doc |
| Brose | Thomas Christian Gerhard | 2nd. Eng |
| Beyer | Mario | 2nd. Eng |
| Haack | Michael Detlev | 2nd. Eng |
| Redmer | Jens Dirk | ELO |
| Kliemann | Olaf | ELO |
| Hüttebräucker | Olaf | ELO |
| Nasis | Ilias | ELO |
| Jäger | Vladimir | ELO |
| Sedlak | Andreas Enrico | Bosun |
| Neisner | Winfried | Carpen. |
| Denzer | Florian | MP Rat. |
| Klee | Philipp | MP Rat. |
| Claasen | Thies | MP Rat. |
| Meier | Jan | MP Rat. |
| Frerichs | Nils | MP Rat. |
| Wende | Uwe | AB |
| Baecker | Andreas | AB |
| Burzan | Gerd-Ekkehard | AB |
| Preußner | Jörg | Storek. |
| Schwarz | Uwe | MP Rat. |
| Grünberg | Niklas | MP Rat. |
| Rhau | Lars-Peter | MP Rat. |
| Klinger | Dana | MP Rat. |
| Hänert | Ove | MP Rat. |

| Name | Vorname | Master |
|---|---|---|
| Jassmann | Marvin | MP Rat. |
| Matter | Sebastuian Udo | Cook |
| Silinski | Frank | Cooksm. |
| Hammelmann | Louisa | Cooksm. |
| Pieper | Daniel | Chief Stew. |
| TBN | | Nurse / Stew. |
| Silinski | Carmen Viola | 2nd Stew. |
| TBN | | 2nd Stew. |
| Krause | Tomasz | 2nd Stew. |
| Arendt | Rene | 2nd Stew. |
| Chen | Dansheng | 2nd Stew. |
| Sun | Yongsheng | Laundym. |