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

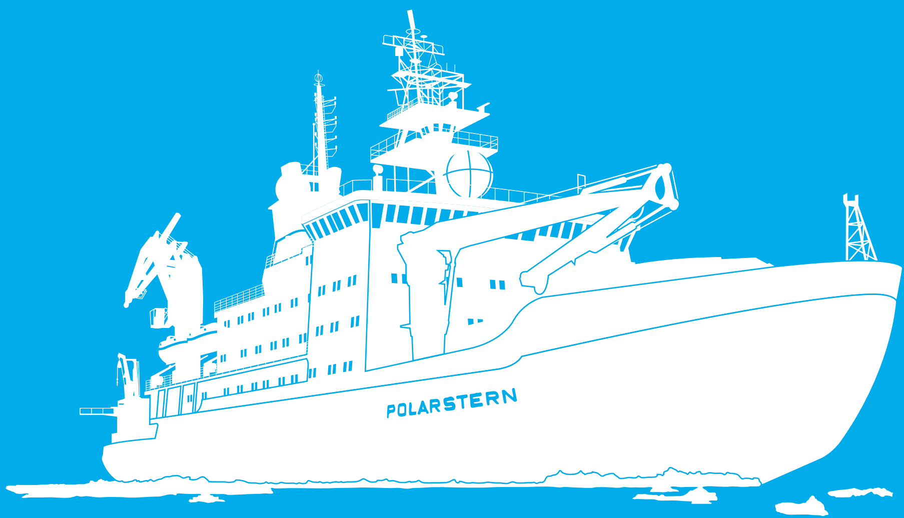
EXPEDITION PROGRAMME
PS146

Polarstern

PS146
Walvis Bay - Port Stanley
24 December 2024 - 10 March 2025

Coordinator: Ingo Schewe

Chief Scientist PS146: Olaf Boebel



HELMHOLTZ

Bremerhaven, December 2024

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

Telefon:	+49 471 4831-0
Telefax:	+49 471 4831-1149
E-Mail:	info@awi.de
Website:	http://www.awi.de
Email Coordinator:	ingo.schewe@awi.de
Email Chief Scientist PS146:	olaf.boebel@awi.de

The Expedition Programme *Polarstern* is issued by
the Alfred Wegener Institute, Helmholtz Centre for Polar and
Marine Research (AWI) in Bremerhaven, Germany.

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

Editorial editing and layout
Susan Amir Sawadkuhi

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

www.awi.de
www.awi.de/en/reports

Contents

1. ÜBERBLICK UND EXPEDITIONSVERLAUF

Olaf Boebel DE.AWI

Die Expedition PS146 des deutschen Forschungsschiffs *Polarstern* soll Beiträge zu wissenschaftlichen Projekten aus den Bereichen physikalische Ozeanografie, Meeresbiologie und Meereschemie erheben. Die Arbeiten zielen darauf ab, die Entwicklung der physikalischen Eigenschaften der Wassermassen des Weddellmeers und der benachbarten Regionen, sowie der ökologischen und chemischen Kreisläufe zu verstehen. Diese Expedition ist eine Fortsetzung der langfristigen Zeitreihenarbeit des HAFOS Projekts (Hybrid Antarctic Float Observation System). HAFOS ist dem Klima, dem Ozean und der Ökosystem-Dynamik im Weddellwirbel gewidmet. Die HAFOS- Zeitreihe geht bis auf die 1980/1990er Jahre zurück, insbesondere bezüglich der Hydrografie, der Nährstoffe, des gelösten Sauerstoffs und des CO2-Systems. Ein weiterer Teil von PS146 befasst sich schwerpunktmäßig mit der ozeanographischen und biogeochemischen Dynamik im Bereich des kontinentalen Schelfabbruchs, dabei koordinierte und systematische Beobachtungen des sympagischen, pelagischen und benthischen Teils des Ökosystems des Weddellmeeres umfassend. Die Expedition beinhaltet folgende Projekte:

- **HAFOS** erforscht, POF 2.3 unterstützend, die Verbreitung und die Entwicklung des Warmen Tiefenwassers (WDW) und des Weddellmeer Bodenwassers (WSBW) mittels ozeanografischer Tiefseeverankerungen, hydrografischer Schnitte mit Messungen von chemischen Variablen, und autonomer Floats, die darüberhinaus das internationale Argo-Projekt bis in das südliche Polarmeer erweitern. Interdisziplinäre Aspekte von HAFOS betreffen die akustische Ökologie des Weddellmeers, dessen Fauna und Schallkulisse im Rahmen von POF 6.4 sowie die Verteilung von gelöstem Sauerstoff, Gesamt-CO2, Alkalinität und Nährstoffen.

- **COSMUS-2** (COntinental Shelf MUltidisciplinary Flux Study) untersucht die ozeanographischen Prozesse, die Zirkulation und die Bildung von Wassermassen auf dem südlichen Kontinentalschelf des Weddellmeeres und bewertet deren Auswirkungen auf das Ökosystem und die Kohlenstoffspeicherung. COSMUS-2 stützt sich auf Langzeit-Verankerungen, schiffsgestützte Wasserprobennahme und die Besenderung von Robben und leistet somit einen Beitrag zu POF 2.1, 2.3 sowie 6.3.

- **SeaCaT** untersucht die jahreszeitliche Produktion, mikrobielle Gemeinschaften und assoziierte Kohlenstoffflüsse mittels autonomer Technologien (ozeanografische und biogeochemische Sensoren, Wasserprobennehmer, Sedimentfallen, Meeresoptik). Ergänzt durch Beprobung mikrobieller und chemischer Parameter während PS146, beleuchtet SeaCaT grundlegende Dynamiken und Treiber der biologischen Kohlenstoffpumpe über Zeit und Raum; mit Beitrag zu POF 6.1 und 6.3.

- **Icefish-1** ist ein multidisziplinäres und internationales Projekt, das darauf abzielt, die räumliche Verteilung, die Vernetzung und die Ökologie der ausgedehnten Neopagetopsis ionah-Eisfischkolonie, die kürzlich an den Flanken des Filchner Tals im Weddellmeer entdeckt wurde, besser zu verstehen. Hochauflösende Kameraarbeit und physische Probenahmen von Fischen und Eiern werden in erster Linie zu POF 6.2 beitragen, aber auch zu POF 6.1, 6.3 und 2.4, indem neuartige Techniken eingesetzt werden, um aktuelle und potenzielle Reaktionen dieser Art auf Umweltveränderungen zu bewerten.

- **SWISS**, die Summer Weddell Sea Ice and Snow Regimes-Studie, zielt darauf ab, das Verständnis für das Verhalten des antarktischen Meereises und seine Reaktion auf den Klimawandel zu verbessern, indem die Eisdicke quantifiziert, die Eigenschaften des Schnees bewertet und Veränderungen von Schnee und Eis mit dem Meereis-Ökosystem durch helikoptergestützte Erhebungen, Probenahmen vor Ort und autonome Bojen im Weddellmeer, insbesondere in der südöstlichen Region, in Verbindung gebracht werden. Das Projekt leistet einen Beitrag zu POF 2.1, indem es wichtige Daten zur Massenbilanz und Thermodynamik des Meereises liefert, und zu POF 6.1, indem es den Einblick in die künftige Funktionsweise des Ökosystems verbessert.

- **COMA** untersucht die Verbreitung und ökologische Funktion mikrobieller psychrophiler antarktischer Mikroorganismen in der Wassersäule (CTD) und Meereis (Kerne). Das Projekt erforscht chemische Treiber mikrobieller Nischenanpassungen und trägt damit zu den Zielen von POF 6.1 und 6.3 bei, z.B. dem Verständnis der Primärproduktion und des mikrobiellen Kohlenstoffkreislaufs im Weddellmeer.

- **Bathymetrische Vermessungen** während PS146 werden dazu beitragen, die Geschichte des antarktischen Eisschildes zu rekonstruieren. Das Wissen über seine Dynamik in der Vergangenheit wird dazu beitragen, seine künftige Entwicklung besser zu verstehen, insbesondere im Hinblick auf die Klimaerwärmung. Dies ist ein Beitrag zum POF IV 2.3 „Sea level change".

Um diese Vorhaben und Ziele umzusetzen, wird *Polarstern* am 24. Dezember 2024 von Walvis Bay, Namibia, auslaufen (Abb. 1.1). Die Fahrt führt durch das Südpolarmeer bis zum Antarktischen Kontinent und zurück, um am 10. März 2025 in Port Stanley, Falklands, zu enden. Dazu werden wir Walvis Bay mit süd-südwestlichem Kurs verlassen, um wenige Tage später den Nullmeridian bei etwa 59°S, nahe der südlichen ACC (Antarctic Circumpolar Current) Front, zu erreichen. Dem Nullmeridian wird südwärts bis zum Erreichen des Antarktischen Kontinents gefolgt, um daraufhin zur Versorgung der *Neumayer-Station* den Atka Seaport anzulaufen. Nach Passage von Kapp Norvegia werden wir den Bereich des Kontinentalabbruchs im südöstlichen Weddellmeer anlaufen, um dort Verankerungen zu tauschen sowie Untersuchungen am Meereis durchzuführen und Robben zu besendern. Hieran schließt sich eine Querung des Weddellmeers im Zickzackkurs zur Nordspitze der Antarktischen Halbinsel bei Joinville Island an, wo ein hochaufgelöster hydrographischer Schnitt erfolgen soll. Schlussendlich setzen wir Kurs Nord und queren die Drakestraße, um wenige Tage später in Port Stanley, Falklands, einzulaufen[1].

1 In Teilen übersetzt aus dem Englischen mit DeepL.com (kostenlose Version)

SUMMARY AND ITINERARY

Expedition PS146 of the German research vessel *Polarstern* will contribute to scientific projects in the fields of physical oceanography, marine biology and marine chemistry. The work aims to understand the development of the physical properties of the water masses of the Weddell Sea and the neighboring regions, as well as the ecological and chemical cycles. This expedition is a continuation of the long-term time series work of the HAFOS project (Hybrid Antarctic Float Observation System). HAFOS is dedicated to climate, ocean and ecosystem dynamics in the Weddell Gyre. The HAFOS time series goes back to the 1980s/1990s, particularly with regard to hydrography, nutrients, dissolved oxygen and the CO2 system. Another part of PS146 focuses on the oceanographic and biogeochemical dynamics in the area of the continental shelf break, including coordinated and systematic observations of the sympagic, pelagic and benthic part of the Weddell Sea ecosystem. This expedition includes the following projects:

- Supporting POF 2.3, **HAFOS** investigates the distribution and evolution of Warm Deep Water (WDW) and the Weddell Sea Bottom Water (WSBW) by means of oceanographic deep-sea moorings, hydrographic transects with measurements of chemical variables, and autonomous floats that further extend the international Argo project into the Southern Ocean. Interdisciplinary aspects of HAFOS concern the acoustic ecology of the Weddell Sea, its fauna and soundscape in the context of POF 6.4 as well as the distribution of dissolved oxygen, total CO2, alkalinity and nutrients.
- **COSMUS-2** (COntinental Shelf MUltidisciplinary Flux Study) investigates oceanographic processes, circulation and water mass formation on the southern Weddell Sea continental shelf and assess their impact on the ecosystem and carbon sequestration. COSMUS-2 is based on long-term moorings, shipboard water sampling, and seal tagging and contributes primarily to POF subtopics 2.1 and 2.3 as well as 6.3.
- **SeaCaT** studies the seasonal productivity, microbial communities, and associated carbon fluxes via autonomous technologies (oceanographic and biogeochemical sensors, water samplers, sediment traps, ocean optics). Complemented by underway sampling of microbial, carbon and nutrient parameters, SeaCaT will discern fundamental dynamics and drivers of the biological carbon pump over time and space; contributing to POF 6.1 and 6.3.
- **Icefish-1** is a multidisciplinary and international project focused on better understanding the spatial distribution, connectivity and ecology of the extensive Neopagetopsis ionah icefish colony recently discovered on the flanks of the Filchner Trough, Weddell Sea. High resolution camera work and physical sampling of fish and eggs will contribute primarily to POF 6.2, with input also into POF 6.1, 6.3 and 2.4 by using novel techniques to assess current and potential responses of the species to environmental change.
- **SWISS**, the Summer Weddell Sea-Ice and Snow-Regimes study, aims to enhance understanding of Antarctic sea-ice behavior and its response to climate change by quantifying ice thickness, assessing snow properties, and linking changes in snow and ice to the sea-ice ecosystem through helicopter-based surveys, on-site sampling, and autonomous buoys in the Weddell Sea, particularly in the southeastern region. It contributes to Subtopic 2.1 by providing key data on sea ice mass balance and

thermodynamics, and to Subtopic 6.1 by improving insights into future ecosystem functionality.

- **COMA** investigates the distribution and ecological function of microbial psychrophilic Antarctic microorganisms in the water column (CTD) and sea ice (thawed cores). Specifically, the project will characterize chemical drivers of microbial niche adaptations and contribute to major aims within POF 6.1 and 6.3, namely to better understand the primary production and the microbial carbon loop in the Weddell Sea.
- The **bathymetric data** collected during PS146 will help to understand the history of the Antarctic Ice Sheet. Knowledge about its dynamics in the past will help to better understand its future development especially in the light of climate warming. This contributes to POF IV 2.3 "sea level change".

To achieve these plans and goals, *Polarstern* will set sail from Walvis Bay, Namibia, on 24 December 2024 (Fig. 1.1). The journey will take us through the Southern Ocean to the Antarctic continent and back, ending in Port Stanley, Falklands, on 10 March 2025. We will leave Walvis Bay on a south-southwesterly course to reach the prime meridian a few days later at around 59°S, close to the southern ACC (Antarctic Circumpolar Current) front. The zero meridian will be followed southwards until the Antarctic continent is reached, after which the ship will call at Atka Seaport to supply *Neumayer Station*. After passing Kapp Norvegia, we will head for the area of the continental break-off in the south-eastern Weddell Sea to swap moorings, conduct sea-ice surveys and track seals. This will be followed by a zigzag crossing of the Weddell Sea to the northern tip of the Antarctic Peninsula near Joinville Island, where a high-resolution hydrographic section will be made. Finally, we will set a northerly course and cross the Drake Strait to enter Port Stanley, Falklands, a few days later[2].

2 Translated in parts from German with DeepL.com (free version)

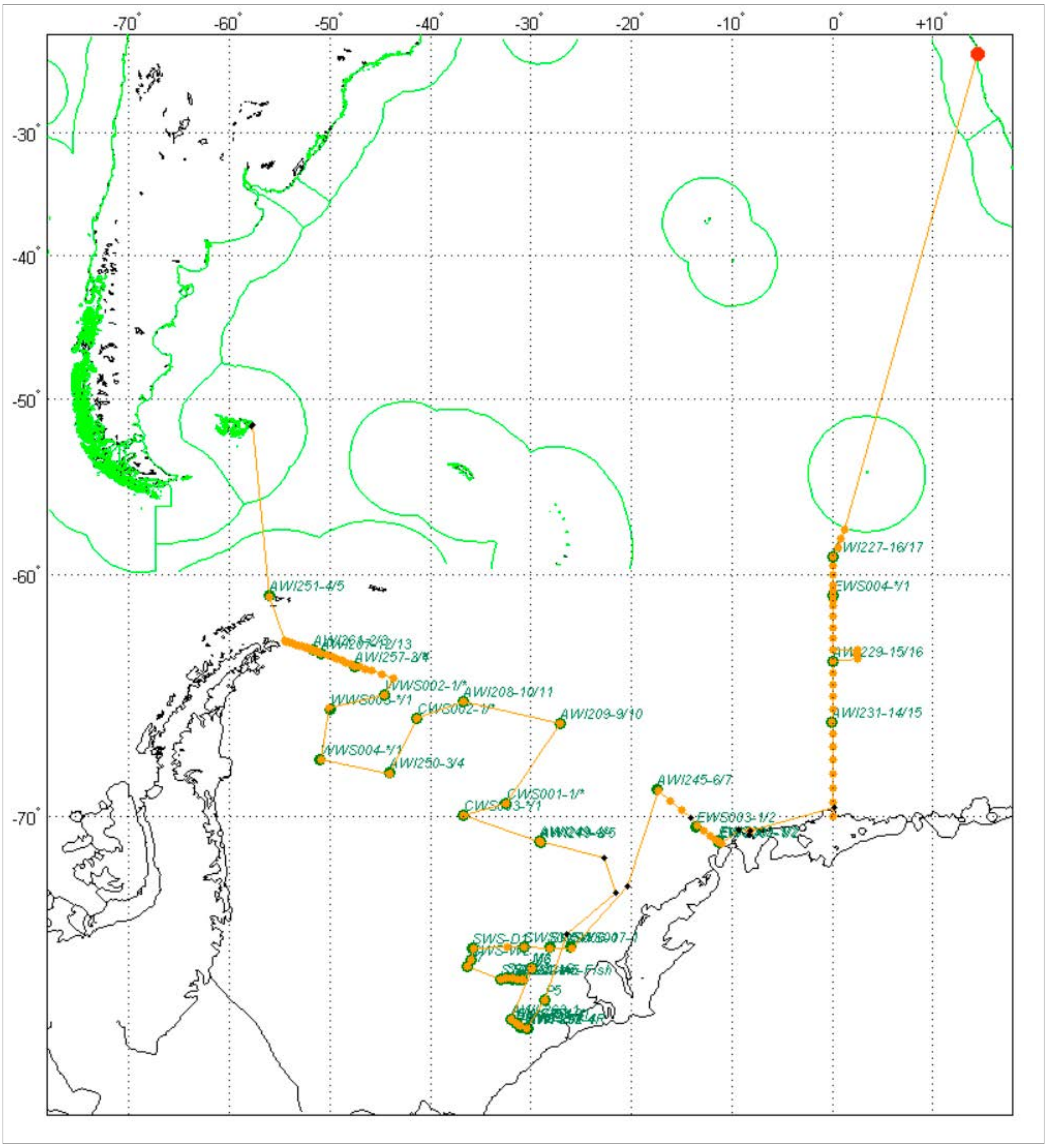


Abb. 1.1: Übersichtskarte des Untersuchungsgebietes mit geplanter Expeditionsroute. Grüne Kreise mit Beschriftungen: Standorte und Namen der zu bergenden ozeanographischen Verankerungen (Beschriftungen mit Ziffern vor dem Schrägstrich) und neu zu verankernde Verankerungen (Beschriftungen mit Ziffern nach dem Schrägstrich). Orange Punkte: Standorte geplanter CTD Stationen. Eisstationen werden entlang der Expeditionsroute innerhalb der Untersuchungsgebietes durchgeführt. Unterwegs-Messungen erfolgen entlang der Expeditonsroute.

Fig. 1.1: Overview map of the study area with planned expedition route. Green circles with labels: Locations and names of oceanographic moorings to be recovered (labels with numbers before the slash) and new moorings to be deployed (labels with numbers after the slash). Orange dots: Locations of planned CTD stations. Ice stations will occur along the track within the overall investigation area. Underway measurements will be conducted continously along the expedition route.

2. HAFOS: MAINTAINING THE AWI'S LONG TERM OCEAN OBSERVATORY IN THE WEDDELL SEA

Olaf Boebel[1*], Fridjof Forthaus[1], Jens Hölemann[1], Martin Losch[1], Matthias Monsees[1], Léa Olivier[1], Emma Robertson[1], Stefanie Spiesecke[1], Krissy Taylor[1], Jan Tebben[1], Sandra Tippenhauer[1], Olga Alejandra Vargas Fonseca[2], Valentina Volkova[1], Andreas Welsch[3], Svenja Wöhle[1], Martina Zapponini[1]
*olaf.boebel@awi.de

[1]DE.AWI
[2]ZA.Mandela
[3]DE.UNI-Hamburg

Grant-No. AWI_PS_146_01

Objectives

The ocean is a key element of the global climate system due to its ability to store and transport large amounts of heat, to act as a sink of carbon dioxide, and due to the sea-ice ocean albedo effect providing positive feedback to sea-ice melting. The response of the ocean to changes in the radiative and wind-driven forcing is controlled by its stratification as governed by the vertical structure of temperature and salinity. Until recently ship-borne observations provided the only means to obtain sufficiently accurate vertical profiles of water mass properties. However, automated systems gained importance during the last two decades. The current backbone of the oceanic observing system is Argo, an internationally financed and organized array of >3000 autonomous profiling floats with public, near-real time data access. However, Argo is by and large restricted to oceanic regions that are ice free year-round, as the floats need to surface regularly to be localized and to transmit their data. Furthermore, Argo does not access the deep ocean.

In an effort to overcome the observational constraints posed by high latitudes and the deep ocean, the Hybrid Antarctic Float Observing System (HAFOS) builds on vertically profiling, custom developed ice-resilient floats (Klatt et al. 2007, Reeve et al., 2016) and a set of deep-sea moorings deployed throughout the Weddell Gyre to record oceanographic data at selected sites. HAFOS also includes an ecological component using passive hydroacoustic recording devices embedded in each of the deep-sea moorings to collect data on the acoustic environment as shaped by manifold biotic and abiotic acoustic sources.

HAFOS was first established in its full extend in 2012/13 during *Polarstern* expedition ANT 29.2, yet subsets of the system existed in various configurations since 2002, allowing for the development and testing of components. The goal of this expedition is to service HAFOS by maintaining the mooring array to allow localizing ice-resilient floats deployed in 2022 and in preparation for the deployment of additional ice-resilient floats next year, also to recover and continue the deep temperature and salinity long-term time series monitoring the state of Antarctic Bottom Water.

Being the physical oceanography core project of this expedition, HAFOS intends to investigate the role of the Southern Ocean in the global climate system with focus on the Atlantic sector, including the Weddell Sea, where the densest bottom waters of the global oceans originate

(Behrendt et al., 2011; Fahrbach, et al. 2011; Fahrbach et al., 2007). The production of these dense water is controlled by the balance between:

- supplies of fresh water through precipitation,
- the melting of continental and sea ice,
- the extraction of freshwater by sea-ice formation and evaporation, and
- a supply of warm and salty water masses as transported by the subpolar gyres towards the continental margins of Antarctica, with the gyres of the Weddell and Ross Seas being their most prominent expressions.

The basic mechanism of dense water generation involves upwelling of Circumpolar Deep Water (CDW), which is relatively warm and salty, into the surface layer where CDW comes into contact with the atmosphere and sea ice becoming cooled and freshened. The newly formed bottom water formed hereby is significantly colder and slightly fresher than the initial Circumpolar Deep Water, which indicates heat loss and the addition of freshwater. Since freshwater input in the upper oceanic layers would impede sinking due to increasing stratification of the water column, it has to be compensated by salt gain through fresh water extraction. Significant parts of salt accumulation occur on the Antarctic shelves in coastal polynyas. With extreme heat losses occurring over ice free water areas, the polynyas are areas of intense sea-ice formation. Offshore winds compress the newly formed sea ice and keep an open sea surface in the polynyas.

The properties and volume of the newly formed bottom water are subject to significant variability on a wide range of time scales, which can only scarcely be explored due to the large efforts needed to obtain measurements in ice covered ocean areas. Seasonal variations of the upper ocean layers are only partially known and normally exceed other scales of variability in intensity. Impacts of longer-term variations of the atmosphere-ice-ocean system, such as the Southern Hemispheric Annular Mode and the Antarctic Dipole, are only poorly monitored and understood. Their influence on or interaction with oceanic conditions are merely guessed on the basis of models which are only superficially validated due to lack of appropriate measurements.

This extreme regional and temporal variability represents a large source of uncertainty when data sets of different origin are combined. Therefore, circumpolar data sets of sufficient spatial and temporal coverage are required and until recently could only be acquired for surface or integral properties by satellite remote sensing. However, to penetrate into the ocean interior and to validate the remotely sensed data, an ocean observing system is required, which combines remotely sensed data of sea ice and surface properties with long-term *in-situ* measurements of ocean interior properties, i.e., HAFOS.

Work at sea

The oceanographic studies during *Polarstern* expedition PS146 will focus on two major areas, the Greenwich Meridian and the Weddell Sea, continuing more than 30 years of *in-situ* observations in the Atlantic sector of the Southern Ocean. Employing moored instruments, we seek to obtain time series of water-mass properties throughout the deep and the surface layers. For this purpose, moorings featuring current meters, temperature and salinity sensors, sound sources and passive acoustic recorders, will be recovered and redeployed (Tab. 2.1 and 2.2). While, during the previous expeditions ANT-29.2, ANT-30.2 (PS89), PS103, PS117 and PS129, the recovery of moorings in ice covered areas was facilitated significantly using the ultra-short line positioning system (POSIDONIA), it nevertheless was not possible to retrieve some moorings due to the ice conditions. For this reason, a ROV has been acquired and developed to recover moorings directly by hooking a recovery rope to the mooring rope.

To enhance the vertical resolution and to calibrate moored sensors, CTD stations will be occupied at the mooring locations. The CTD/Rosette will be operated using the standard SeaBird SBE911plus setup, equipped with double sensors for temperature, salinity, and oxygen and one sensor each for pressure, substance fluorescence Chl. a (WET Labs ECO-AFL/FL), substance fluorescence of coloured dissolved organic matter (CDOM, WET Labs ECO CDOM), yellow substance fluorescence (Dr. Haardt), beam transmission (WET Labs C-Star), photosynthetically active radiation (PAR/Logarithmic, Satlantic), and surface photosynthetically active radiation (SPAR/Linear, Satlantic). In addition, 24 12-liter Niskin bottles for water sampling will be attached. An altimeter will be mounted to monitor the distance to the seafloor. Additionally up and downward looking Workhorse LADCPs will be mounted to the rosette to measure the current velocity profile.

Moorings will contain sound sources, providing RAFOS signals for retrospective under-ice tracking of 21 ice resilient APEX floats deployed during PS146 (Tab. 2.3) and passive acoustic recorders to record ambient (biotic and abiotic) sounds. During PS146, 4 Core-Argo and 1 GGC-Argo floats will be deployed for the Bundesamt für Seeschifffahrt und Hydrographie (BSH, Tab. 2.4) across the ACC throughout the Weddell Sea. Further 10 biogeochemical Argo floats shall be deployed for Scripps Oceanographic Institution (Tab. 2.5). A CTD/I-ADCP section shall be repeated between mooring AWI 257 (near 47.5°E) and the tip of the Antarctic Peninsula, aiming at delineating the export plume of Antarctic Bottom Water.

Tab. 2.1: List of moorings scheduled for RECOVERY during PS146.

#	Mooring ID	Latitude	Longitude	Water depth [m]
1	AWI227-16	59° 02.98’ S	00° 06.49’ E	4774
2	UK1	63° 31.97’ S	02° 26.59’ E	4479
3	UK2	63° 41.22’ S	02° 25.90’ E	3519
4	UK3	63° 41.83’ S	02° 23.86’ E	3477
5	UK4	63° 55.06’ S	02° 26.77’ E	2773
6	AWI229-15	64° 01.22’ S	00° 00.82’ E	5056
7	AWI 231-14	66° 31.04’ S	00° 04.48’ W	4543
8	EWS 001-1	70° 52.40’ S	11° 14.36’ W	561
9	EWS 002-01	70° 50.29’ S	11° 26.07’ W	1392
10	EWS 003-01	70° 17.90’ S	13° 26.78’ W	3421
11	AWI 245-06	69° 06.66’ S	17° 15.10’ W	4762
12	SWS07-01	74° 01.34’ S	25° 58.29’ W	2884
13	SWS06-01	74° 01.34’ S	28° 07.04’ W	2526
14	SWS05-01	74° 00.16’ S	30° 41.55’ W	2146
15	AWI 256-2	74° 00.16’ S	32° 22.40’ W	1844
16	SWS-D1/01	74° 02.95’ S	35° 44.22’ W	2183
17	SWS-W2/01	74° 20.74’ S	35° 56.11’ W	1528
18	P7 (FRA)	74° 31.11’ S	36° 19.87’ W	813
19	S2-2021-W (NOR)	74° 51.04’ S	32° 59.27’ W	600
20	S2-2021-C (NOR)	74° 49.78’ S	32° 31.04’ W	600
21	S2-2021-E (NOR)	74° 50.86’ S	31° 49.73’ W	600
22	P2-01 (FRA)	74° 51.22’ S	31° 22.89’ W	600
23	P1-01 (FRA)	74° 51.22’ S	30° 59.48’ W	540

#	Mooring ID	Latitude	Longitude	Water depth [m]
24	SWS-WetCam /01	74° 51.58' S	30° 47.78' W	496
25	M3-01 (NOR)	74° 32.95' S	29° 54.12' W	765
26	M6	74° 35.53' S	29° 54.63' W	581
27	AWI263-01	75° 53.01' S	31° 57.14' W	732
28	AWI 254-4	75° 58.38' S	31° 28.76' W	570
29	SWS03-01 aka AWI 254-4R	75° 58.38' S	31° 28.76' W	570
30	AWI 253-4	76° 02.53' S	31° 00.86' W	459
31	AWI 252-4	76° 06.15' S	30° 28.67' W	497
32	AWI 252-4R aka SWS01-01	76° 06.15' S	30° 28.67' W	497
33	P5	75° 23.32' S	28° 36.93' W	450
34	AWI 249-4	70° 49.93' S	29° 07.93' W	4384
35	AWI 249-3	70° 53.22' S	28° 56.97' W	4367
36	CWS 01-01	69° 33.35' S	32° 28.62' W	4461
37	AWI 209-09	66° 36.44' S	27° 07.27' W	4844
38	AWI 208-10	65° 41.76' S	36° 40.97' W	4701
39	CWS 002-01	66° 22.76' S	41° 23.50' W	4457
40	AWI 250-3	68° 31.33' S	44° 02.53' W	4093
41	WWS 002-01	65° 25.20' S	44° 35.57' W	4390
42	AWI 257-03	64° 14.42' S	47° 29.11' W	4177
43	AWI 257-02	64° 12.94' S	47° 29.38' W	4171
44	AWI207-12	63° 39.36' S	50° 48.66' W	2494
45	AWI 261-02	63° 30.89' S	51° 38.2' W	1730
46	AWI251-4	61° 01.38' S	55° 58.68' W	264

Tab. 2.2: List of moorings scheduled for DEPLOYMENT during PS146.

#	Mooring ID	Latitude	Longitude	Water depth [m]
1	AWI227-17+BGC	59° 02.98' S	00° 06.49' E	4774
2	EWS 004/01	61° 00.00' S	00° 00.00' E	5437
3	AWI231-BGC	66° 31.04' S	00° 04.48' W	4543
4	AWI231-15	66° 31.04' S	00° 04.48' W	4543
5	EWS 002-02+BGC	70° 50.29' S	11° 26.07' W	1392
6	AWI245-07	69° 06.66' S	17° 15.10' W	4762
7	SWS07-02	74° 01.34' S	25° 58.29' W	2884
8	SWS05-02	74° 00.16' S	30° 41.55' W	2146
9	SWS-D1/02	74° 02.95' S	35° 44.22' W	2183
10	P7 (FRA)	74° 31.11' S	36° 19.87' W	813
11	S2-2021-W (NOR)	74° 51.04' S	32° 59.27' W	600
12	P2-02 (FRA)	74° 51.22' S	31° 22.89' W	600
13	P1-02 (FRA)	74° 51.22' S	30° 59.48' W	540
14	SWS-WetCam /02	74° 51.58' S	30° 47.78' W	496
15	M3-02 (NOR)	74° 32.95' S	29° 54.12' W	765

#	Mooring ID	Latitude	Longitude	Water depth [m]
16	AWI 254-5	75° 58.38' S	31° 28.76' W	570
17	AWI 253-5	76° 02.53' S	31° 00.86' W	459
18	AWI 252-5	76° 06.15' S	30° 28.67' W	497
19	AWI 249-5	70° 53.22' S	28° 56.97' W	4367
20	CWS 003-01	69° 58.21' S	36° 41.33' W	4249
21	AWI 209-10	66° 36.44' S	27° 07.27' W	4844
22	AWI 208-11	65° 41.76' S	36° 40.97' W	4701
23	AWI-208 BGC	65° 41.76' S	36° 40.97' W	4701
24	AWI 250-04	68° 31.33' S	44° 02.53' W	4093
25	WWS 004-01	68° 00.10' S	50° 49.39' W	3264
26	WWS 003-01	65° 59.15' S	50° 04.75' W	3317
27	AWI207-13	63° 39.36' S	50° 48.66' W	2494
28	AWI 261-3+BGC	63° 30.89' S	51° 38.20' W	1730
29	Danger Island	63° 09.70' S	54° 23.39' W	500
30	AWI251-5	61° 01.38' S	55° 58.68' W	264

For Table 2.3, 2.4 and 2.5 please see the end of the cchapter.

Expected) results

We expect to secure data from a large proportion of the instruments currently moored, together with ship-based CTD- and lowered ADCP data. Particulary, first results regearding the steady warming of the Weddell Sea Bottom Water continues are expected to emerge during the expedition.

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 expedition at the latest. By default, the CC-BY license will be applied.

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

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topics 2 and 6, Subtopics 2.3, and 6.4.

In all publications based on this expedition, the **Grant No. AWI_PS129_01** 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.

References

Behrendt A, Fahrbach E, Hoppema M, Rohardt G, Boebel O, Klatt O, Wisotzki A, Witte H (2011) Variations of Winter Water properties and sea ice along the Greenwich meridian on decadal time scales. Deep-Sea Research II 58:2524-2532. https://doi:10.1016/j.dsr2.2011.07.001

Fahrbach E, Hoppema M, Rohardt G, Boebel O, Klatt O, Wisotzki A (2011) Warming of deep and abyssal water masses along the Greenwich meridian on decadal time scales: The Weddell gyre as a heat buffer. Deep Sea Research Part II 58:2509-2523. https://doi:10.1016/j.dsr2.2011.06.007

Fahrbach E, Boebel O, Hoppema M, Klatt O, Rohardt G, Schröder M, Wisotzki A (2007) Decadal scale variations of water mass properties in the Weddell Sea. NOTUS: the AGCS Newsletter 2. https://epic.awi.de/id/eprint/21649/

Klatt O, Boebel O, Fahrbach E (2007) A profiling floats sense of ice , Journal of Atmospheric and Oceanic Technology 24:1301-1308. https://doi:10.1175/JTECH2026.1

Reeve K, Boebel O, Kanzow T, Strass V, Rohardt G, Fahrbach E (2016) A gridded data set of upper-ocean hydrographic properties in the Weddell Gyre obtained by objective mapping of Argo float measurements. Earth System Science Data 8:15-40. https://doi:10.5194/essd-8-15-2016

Tab. 2.3: List of planned ice resilient Argo float deployments during PS146. All floats are of type APEX by Teledyne Webb Research and their planned deployments have been registered with www.ocean-ops.org.

ID	Apex float S/N	WMO	IMEI	ICCID	Deployment latitude	Deployment longitude	Water depth [m]
PS146-TBD	9214	7900989	300125062936380	8988169234002513752			
PS146-TBD	10361	6990681	300125062133270	8988169234005407820			
PS146-TBD	10362	3902632	300125062455510	8988169234005407838			
PS146-TBD	10363	2903957	300125062451510	8988169234005408463			
PS146-TBD	10364	3902633	300125062452510	8988169234005408471			
PS146-TBD	10365	1902735	300125062450400	8988169234005408489			
PS146-TBD	10366	2903958	300125062458500	8988169234005408497			
PS146-TBD	10367	7902253	300125062458390	8988169234005408505			
PS146-TBD	10368	4903841	300125062454500	8988169234005408513			
PS146-TBD	10369	7902254	300125062455390	8988169234005408521			
PS146-TBD	10370	4903842	300125062458490	8988169234005408539			
PS146-TBD	9952	3902634	300125062718180	8988169234004842654			
PS146-TBD	9953	3902635	300125062918350	8988169234004842662			
PS146-TBD	9954	5907145	300125062818530	8988169234004842670			
PS146-TBD	9955	4903843	300125062717070	8988169234004842688			
PS146-TBD	9956	2903959	300125062918360	8988169234004842696			
PS146-TBD	9957	1902736	300125062818540	8988169234004386108			
PS146-TBD	10049	3902636	300125061197230	8988169234004386116			
PS146-TBD	10865	2903960	300125062399680	8988169234005407804			
PS146-TBD	10866	3902637	300125062297830	8988169234005407796			
PS146-TBD	10867	6990682	300125062296850	8988169234005407788			
backup	10868	1902737	300125062292840	8988169234005407770			
backup	10869	2903961	300125062298550	8988169234005407762			
backup	10870	3902638	300125062290860	8988169234005407754			
backup	10871	4903844	300125062292820	8988169234005407747			
backup	10872	1902738	300125062298810	8988169234005407739			
backup	10873	7902255	300125062294870	8988169234005407721			
backup	10874	6990683	300125062299800	8988169234005407713			
backup	10875		300125062395670	8988169234005910500			

Tab. 2.4: List of planned standard Argo float deployments during PS146. All floats provided by NKE.

ID	Type	S/N	WMO	Deployment latitude	Deployment longitude
PS129-BSH1	Arvor	AI2600-24DE015	7902172	40°S	8°E
PS129-BSH2	Arvor	AI2600-24DE016	7902173	50°S	5°E
PS129-BSH3	Arvor	AI2600-24DE017	7902174	61°S	0°
PS129-BSH4	Arvor	AI2600-24DE018	7902175	65°S	0°
PS129-BSH5	CTS5 Provor BGC	P53387-24DE001	7902176	67°S	0°

Tab. 2.5: List of planned biogeochemical Argo float deployments during PS146. All floats provided by Scripps Oceanographic Institution.

ID	Float S/N	ICCID	IMEI	Deployment latitude	Deployment longitude	Water depth [m]
PS146-SIO1	22044	8988169234005978226	300125062537430	58° 0.00' S	03° 00.00'E	4750
PS146-SIO2	22081	8988169234005978309	300125062633960	59° 2.98' S	00° 06.49'E	4950
PS146-SIO3	22715	8988169234005115852	300125061197240	62° 0.00'S	00° 00.00'W	5280
PS146-SIO4	22953	8988169234005977681	300125062834600	64° 0.00'S	00° 00.00'W	4450
PS146-SIO5	22219	8988169234005977665	300125062432520	68° 0.00'S	00° 00.00'W	2800
PS146-SIO6	22743	8988169234005977723	300125062839590	68° 0.00'S	18° 00.00'W	4850
PS146-SIO7	22732	8988169234005977731	300125062634960	70° 0.00'S	37° 00.00'W	4210
PS146-SIO8	22186	8988169234005977707	300125062932390	67° 0.00'S	28° 00.00'W	4730
PS146-SIO9	22551	8988169234005977590	300125062532400	65° 0.00'S	38° 00.00'W	4720
PS146-SIO10	22264	8988169234005977616	300125062733240	66° 0.00'S	50° 00.00'W	3460

3. COSMUS II: OCEANOGRAPHIC CONDITIONS IN THE SOUTHEAST WEDDELL SEA FROM MOORINGS, TRACERS, AND TAGGED SEALS

M. Janout*[1], L. Aschenbeck[2], H. Bornemann[1], M. Holtappels[1], O Huhn[2], L. Middleton[3], C. Mosneron-Dupin[4], S. Østerhus[5], A. Rogge[1], H. Schröder[1], M. Wege[6]
Not on board: E. Darelius[7], J.-B. Sallée[4], A. Wåhlin[3]
*markus.janout@awi.de

[1]DE.AWI
[2]DE.Uni-Bremen
[3]SW.GU
[4]FR.LOCEAN.UPMC
[5]NO.NORCE
[6]NZ.Uni-Canterbury
[7]NO.Uni-Bergen

Grant-No. AWI_PS146_02

Objectives

The Filchner Trough in the southeastern Weddell Sea is the main conduit for northward flowing Ice Shelf Water (ISW), defined by temperatures below the surface freezing point (Fig. 3.1). ISW originates from High Salinity Shelf Water (HSSW), formed on the continental shelf in front of Ronne Ice Shelf, and carries the glacial melt from the Filchner-Ronne Ice Shelf (FRIS). The ISW pathway within the trough varies on seasonal time scales with flow out of the Filchner Ice Shelf cavity occurring on the western slope only during late summer/early fall (Janout et al., 2021). On its way to the continental shelf break, ISW encounters a seasonal inflow of modified Warm Deep Water (mWDW), flowing along the eastern slope of the trough towards the ice shelf front (Ryan et al., 2017, 2020). ISW dominates at the trough's sill where mixing with open ocean waters forms the deep and bottom waters of the Weddell Sea, the former being the precursor of Antarctic Bottom Water and thus one of the main contributors to the lower branch of the global thermohaline circulation (Foldvik et al., 2004). Projections based on the output of our coupled sea ice – ocean-ice shelf models indicate that in the near future the density of HSSW and, thus, of ISW at the Filchner Trough sill might decrease such that unmodified Warm Deep Water (WDW) can enter the trough and penetrate into the deep Filchner-Ronne Ice Shelf (FRIS) cavity (Hellmer et al., 2012, 2017). The presence of WDW underneath FRIS, similar to the ice shelves fringing the Amundsen Sea to date, is bound to cause a dramatic increase in basal melting. The latter changes ice shelf thickness, reduces the buttressing effect of bottom topography and ultimately influences the dynamics of the ice streams draining the West and East Antarctic Ice Sheets (Timmermann and Goeller, 2017). The resulting freshwater input will have a profound impact on the structure of the shelf water column, the sea ice cover, the formation of deep and bottom waters, and the melting at the base of ice shelves located downstream (Timmermann and Hellmer, 2013).

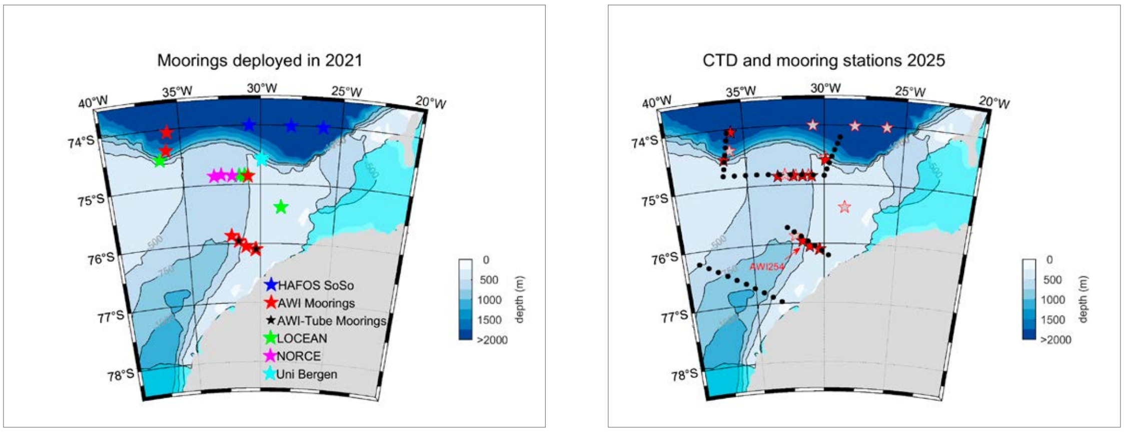


Fig. 3.1: a) Left: Overview of the 2021-moorings to be recovered in 2025. Note that the colour of symbols identifies different operators and mooring types. b) Right: Proposed CTD stations (black dots) and locations of moorings to be deployed in 2025 (red stars). Please note that the southernmost CTD transect is not considered in the time budget and may be occupied only in case of faster than expected progress due to anomalously low sea ice conditions.

COSMUS-II is closely connected to ongoing monitoring of hydrographic properties underneath the Filchner Ice Shelf in the framework of the Filchner Ice Shelf Project (FISP), and furthermore contributes to a multidisciplinary understanding of the region by supporting other side user projects focused on this region (SEACAT, ICEFISH, SWISS). The fieldwork is designed to (a) extend existing data sets from the southern Weddell Sea continental shelf, necessary for the initialization and validation of our coupled ice shelf – ice sheet models (FESOM), and (b) build-up a reference data set to identify changes within the ocean/ice shelf/ice sheet system, expected to occur due to climate change.

General objectives:

- Specify the controls on the slope front dynamics and flow of water masses of open ocean origin onto the southern Weddell Sea continental shelf.
- Determine the temporal variability of the hydrography and tracer distribution in the Filchner Trough with regard to Ice Shelf Water outflow, Antarctic Bottom Water formation, and southward propagation of modified Warm Deep Water.
- Identify temporal and spatial hydrographic trends by means of mooring observations, shipboard surveys and seal tagging.
- Provide a comprehensive dataset for numerical model validation and initialisation of coupled ocean – ice shelf – ice sheet models.

Specific objectives:

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

The combination of ship- and seal-tag-CTD profiles combined with long-term moorings in the Filchner Trough and underneath the Filchner Ice Shelf aims at describing the present physical environment in the southern Weddell Sea, and to monitor its variability and trends.

Tracer observations will further help to quantify:

- Antarctic Bottom Water formation (transient trace gases [CFCs] to identify transit time scales and formation rates), and the interannual variability by comparison with previous expeditions (e.g., PS96 in 2015-2016, PS111 in 2018, PS124 in 2021).

Work at sea

The work programme of COSMUS-II is centered around the servicing of oceanographic moorings, complemented by shipboard CTD-profiling, water column sampling, and seal tagging. The major operational effort is the recovery of 19, and the re-deployment of 12 moorings (Fig. 3.1). The moorings are primarily designed to monitor the pathway of the warm mWDW towards the Filchner Ice Shelf, as well as to trace the shelf- and ice shelf-formed dense and cold water masses as they exit from the continental shelf. In particular, three moorings on the eastern slope of Filchner Trough at 76°S will update and continue a time series that was first established in 2014. These records previously helped to identify the strong seasonality of modified warm water intrusions (Ryan et al., 2017), and showed an 'Exceptionally Warm and Prolonged Flow of Warm Deep Water Toward the Filchner-Ronne Ice Shelf in 2017' (Ryan et al., 2020). All moorings will operate over a time span of 2 to 4 years. The AWI-operated moorings are complemented by a cooperation with Norwegian (NORCE and the University of Bergen), Swedish (University of Gothenburg) and French (LOCEAN) partners, for which we will recover moorings at the Filchner Sill and the continental slope (Fig. 3.1). Furthermore, we will service three moorings installed along the 2,000-m isobath off Brunt Ice Shelf at 74°S carrying a RAFOS array with 3 sound sources to assign positions to profiling APEX floats under the sea ice expected to monitor hydrographic properties around the Antarctic Slope Front.

In addition to the mooring operations, we will carry out approximately 30 profiles with the CTD/water bottle system to acquire hydrographic data and water samples as outlined in Fig. 3.1. From the full-depth profiling casts we intend to obtain about 300 water samples for CFC analyses as well as water samples to be analysed within the activities planned in the SEACAT project. To meet our objectives, CTD stations will be aligned in transects (1) normal to the Filchner Trough axis, (2) across the Filchner Trough sill, and (3) across the slope front and down the continental slope following the path of ISW/WSBW. Meeting the objectives outlined above will require an estimated station time of 14 days in the study region (helicopter operations are not assumed to consume relevant ship time). In order to increase the temporal and spatial CTD coverage, 13 Weddell Seals will be tagged with CTD sensors to 'operate' on the ice-covered southwestern continental shelf during the austral winter months.

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

Preliminary (expected) results

- Improved understanding of the slope front dynamics in the southern Weddell Sea.
- Extension (by four years) of the time series (2014-2021) on the eastern slope of the Filchner Trough based on moorings from 76°S.
- Improved understanding of the dense water export on the continental slope west of the Filchner Trough

- Extended information about the temporal variability and strength of the southward flowing mWDW on the eastern slope of the Filchner Trough.
- Improved understanding of the spreading and pathways of ISW in the Filchner Trough and across the Filchner-Trough sill.

Data management

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

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

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

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

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

In all publications, based on this cruise, the **Grant No. AWI_PS146_02** will be quoted and the following *Polarstern* article 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 Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany.

References

Darelius E, Sallee J-B (2018) Seasonal outflow of ISW from the Filchner Ice Shelf cavity. Geophys. Res. Lett., 45(8), 3577-3585, https://doi.org/10.1002/2017GL076320.

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

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

Hellmer HH, Kauker F, Timmermann R, Determann J, Rae J (2012) Twenty-first-century warming of a

large Antarctic ice-shelf cavity by a redirected coastal current. Nature, 485, 225-228.

Hellmer HH, Kauker F, Timmermann R, Hattermann T (2017) The fate of the southern Weddell Sea continental shelf in a warming climate. J. Clim., 30, 4337-4350, https://doi.org/10.1175/JCLI-D-16-0420.1.

Janout MA, Hellmer H, Hattermann T, Huhn O, Sültenfuss J, Østerhus S, Stulic L, Ryan S, Schröder M, Kanzow T. „FRIS Revisited in 2018: On the Circulation and Water Masses at the Filchner and Ronne

Ice Shelves in the Southern Weddell Sea“. Journal of Geophysical Research: Oceans 126, Nr. 6 (2021): e2021JC017269. https://doi.org/10.1029/2021JC017269.

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

Ryan S, Hellmer HH, Janout M, Darelius E, Vignes L, Schröder M (2020) Exceptionally Warm and Prolonged Flow of Warm Deep Water Toward the Filchner‐Ronne Ice Shelf in 2017. Geophys. Res. Lett., 47(13), https://doi.org/10.1029/2020GL088119.

Timmermann R, Hellmer HH (2013) Southern Ocean warming and increased ice shelf basal melting in the twenty-first and twenty-second centuries based on coupled ice-ocean finite-element modelling , Ocean Dynamics, 63(9), 1011-1026, https://doi.org/10.1007/s10236-013-0642-0.

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

4. SEASONALITY OF CARBON TURNOVER IN THE WEDDELL SEA (SEACAT)

Matthias Wietz[1,2*], Jakob Barz[1], Andreas Rogge[1], Henning Schröder[1], Simone Le Chevère[1], Ombeline Jouet[1], Markus Janout[1], Jan Tebben[1], Moritz Holtappels[1]
not on board: Sinhué Torres-Valdés[1]
*matthias.wietz@awi.de

[1]DE.AWI
[2]DE.UNI-Oldenburg

Grant-No. AWI_PS146_03

Objectives

The seasonal dynamics of the biological carbon pump in the Weddell Sea, including the key organisms that drive biogeochemical processes, are poorly resolved (Hauck et al. 2023). The same applies for the biogeochemical role of dense bottom waters. Both processes are important for the carbon cycle, but highly sensitive to global warming and sea-ice loss; necessitating a detailed quantitative and qualitative understanding.

SeaCaT will perform biogeochemical and biological sampling to study the seasonal productivity in the mixed layer, and quantify associated carbon fluxes. Specifically, continuous records of biodiversity, biogeochemistry and oceanography − across organismal groups, ecosystem compartments, and seasonal states – are obtained via moored sensors and samplers (CTD, pH, pCO_2, O_2, chlorophyll) in the upper mixed layer. Two further moorings will additionally employ autonomous water samplers (RAS), high-frequency particle imagers (UVP), and sediment traps to study carbon export and benthopelagic coupling. Similar endeavors have successfully elucidated annual ecosystem structuring in the Arctic (Wietz et al. 2021, von Appen et al. 2021, Priest et al. 2023)temperature, ice cover, and mixed layer depth. However, the diversity and ecology of microbes across these contrasting environmental conditions remain enigmatic. Here, using autonomous samplers and sensors deployed at two mooring sites, we portray an annual cycle of microbial diversity, nutrient concentrations and physical oceanography in the major hydrographic regimes of the Fram Strait. The ice-free West Spitsbergen Current displayed a marked separation into a productive summer (dominated by diatoms and carbohydrate-degrading bacteria, and during a first year-round study in the Weddell Sea (Hellmer & Holtappels 2021; also see current DFG project by M. Wietz). The year-round data (planned recovery of moorings in early 2026) will be complemented by ship-based sampling along the cruise track; targeting organic and inorganic carbon species, nutrients, as well as microbial community structure in seawater and sea-ice (optional; in cooperation with SWISS project).

In summary, SeaCaT establishes a quantitative and qualitative understanding of seasonal carbon fluxes (vertical and lateral) and associated biodiversity via these objectives:

- Identify keystone taxa and genes that drive seasonal ecosystem structuring and benthopelagic coupling

- Define a spatiotemporal framework by linking seasonality to geographic distribution (i.e. integrating autonomous and ship-based evidence)
- Establish mixed-layer carbon budgets and seasonal air-sea CO2 fluxes
- Measure seasonal primary production and carbon sequestration
- Quantify carbon inventories of specific water masses, and the injection of carbon compounds via dense water export from the shelf into the deep Weddell Sea
- Investigate the fate of organic carbon (POC and DOC) exported with dense water masses, and assess their potential to feed deep-sea fauna

Work at sea

SeaCaT includes mooring and shipboard work in different regions of the Weddell Sea, as detailed in Figure 4.1 and Table 4.1.

Moorings: We will add mixed-layer-extensions to three HAFOS moorings (BGC-25-1, BGC-25-3, BGC-25-5), reaching from the terminal upper end (approx. 250 m depth) into surface waters (approx. 40 m depth). The extension will carry a package of sensors to measure conductivity, temperature, depth, O_2, pH, pCO_2, and chlorophyll. A releaser allows separate recovery of the extension after one year (planned for expedition PS152). In addition, at two stand-alone moorings (BGC-25-2 and BGC-25-4) the sensor package will be complemented by automated Remote Access Samplers (RAS) to collect water samples every week, used for nutrient and eDNA microbiome analyses. Furthermore, an autonomous intelligent camera system (Underwater Vision Profiler 6lp, UVP6) will be situated at approx. 250 m depth for particle and zooplankton imaging. At 1600 m depth (BGC-25-4) and 500 m above bottom (BGC-25-2), sediment traps will be deployed to collect sinking particles.

Water column sampling: Sampling aligns with the HAFOS CTD program. Sampling will focus on transects off Kapp Norvegia / Joinville Island, monitoring the freshwater inflow and water masses exiting to the north respectively. Lower-frequency sampling will be done along the meridian and in the central gyre. Samples will be processed and stored for later analysis of carbon species (DIC and TA, DOC, POC, PIC, C isotopes, nutrients) and microbial diversity (eDNA metabarcoding) in the home lab. Water sampling will be complemented by continuous measurements via the ship's ferrybox devices (salinity, temperature, turbidity, chlorophyll-a, O_2, pH, pCO_2, nutrients). In addition, the AUTOFIM system (Metfies et al. 2016) will autonomously filter water underway for microbial analyses, increasing the spatial dimension of biodiversity records without extra station time. The CTD is furthermore equipped with an UVP 5hd to record particle and mesoplankton distribution.

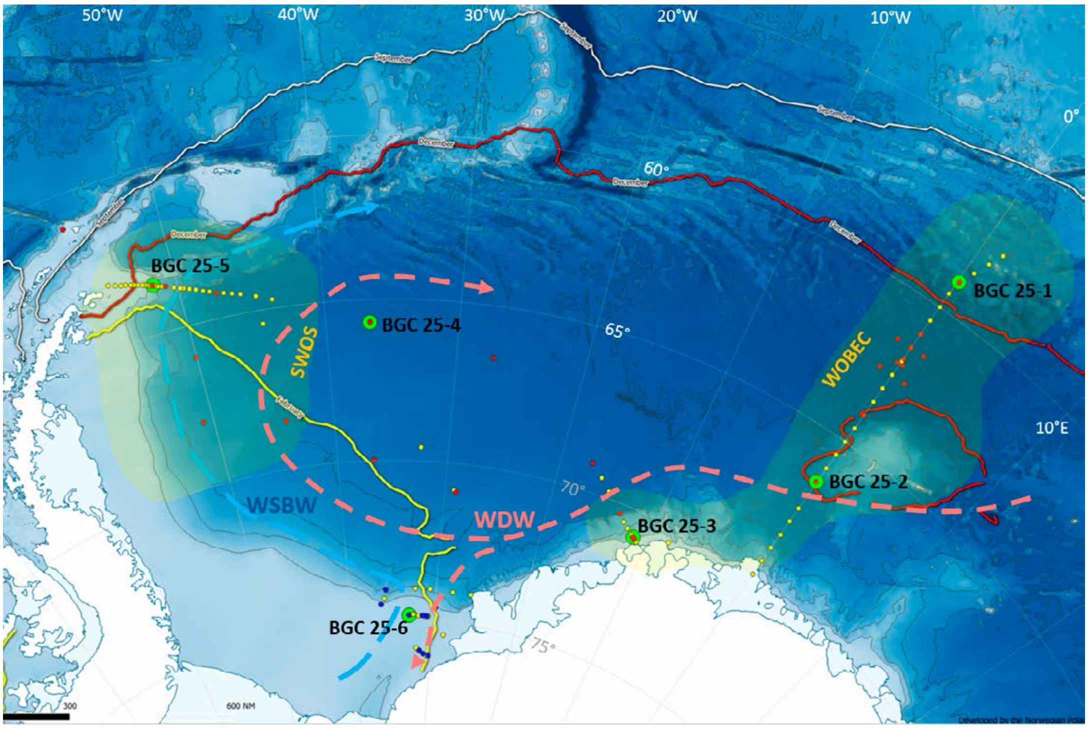


Fig. 4.1: Working area, with circulation pattern for Warm Deep Water (WDW) and Weddell Sea Bottom Water (WSBW) indicated. Median sea-ice extent: September (white line), December (red line), February (yellow line). HAFOS moorings (red dots), CTD stations (yellow dots) and BGC moorings (green dots) are marked. Working areas of the planned WOBEC and SWOS expeditions in 2026 (options for mooring recoveries) are shaded.

Tab. 4.1: BGC moorings

BGC Mooring-ID	HAFOS Mooring-ID	Latitude	Longitude	Water Depth	Comment
BGC-25-1	AWI227-17	59° 2.98' S	0° 6.49' E	4774 m	HAFOS Mixed Layer Extension
BGC-25-2	AWI231-15	66° 31.04' S	0° 4.48' W	4543 m	SeaCaT stand-alone
BGC-25-3	EWS 002-02	70° 50.29' S	11° 26.07' W	1392 m	HAFOS Mixed Layer Extension
BGC-25-4	AWI 208-11	65° 41.76' S	36° 40.97' W	4701 m	SeaCaT stand-alone
BGC-25-5	AWI 261-3	63° 30.89' S	51° 38.2' W	1730 m	HAFOS Mixed Layer Extension
BGC-25-6	SWS-WetCAm	74°51.66' S	30°48.54'W	523 m	HAFOS Mixed Layer Extension

Expected results

We expect detailed and seasonal insights into the biological carbon pump, expanding upon ongoing research on year-round patterns in the polar oceans using a comparable mooring approach (Wietz et al. 2021, von Appen et al. 2021) temperature, ice cover, and mixed layer depth. However, the diversity and ecology of microbes across these contrasting environmental conditions remain enigmatic. Here, using autonomous samplers and sensors deployed at two mooring sites, we portray an annual cycle of microbial diversity, nutrient concentrations and physical oceanography in the major hydrographic regimes of the Fram Strait. The ice-free West Spitsbergen Current displayed a marked separation into a productive summer (dominated by diatoms and carbohydrate-degrading bacteria. A current project with strong links to SeaCaT has indicated marked seasonality of bacteria and particles (Fig. 4.2). SeaCaT will continue these temporal insights and provide an essential time-series perspective on key biogeochemical dynamics in an understudied system.

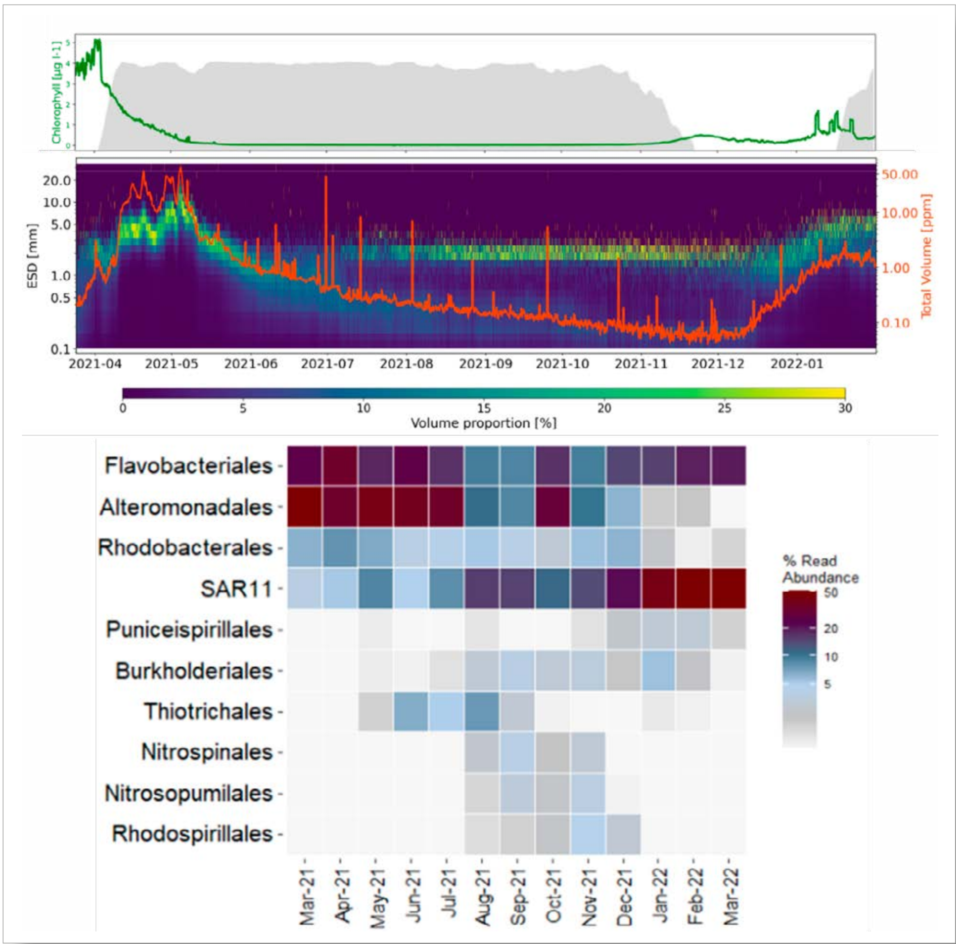


Fig. 4.2: Seasonal dynamics in the central Weddell Gyre as revealed by moored autonomous samplers. Top: Annual sea-ice (grey) and chlorophyll concentrations at 50 m depth. Middle: total particle volume (red) and size distribution (colour: % of the respective size class on total volume) at 250 m depth. Bottom: Bacterial composition over the annual cycle.

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 expedition at the latest. By default, the CC-BY license will be applied.

Molecular data (DNA sequences) 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 6, Subtopics 6.1, 6.2, 6.3.

In all publications based on this expedition, the **Grant No. AWI_PS146_03** 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.

References

von Appen W-J, Waite AM, Bergmann M, Bienhold C, Boebel O, Bracher A, Cisewski B, Hagemann J, Hoppema M, Iversen MH, Konrad C, Krumpen T, Lochthofen N, Metfies K, Niehoff B, Nöthig E-M, Purser A, Salter I, Schaber M, Scholz D, Soltwedel T, Torres-Valdes S, Wekerle C, Wenzhöfer F, Wietz M, Boetius A (2021) Sea-ice derived meltwater stratification slows the biological carbon pump: results from continuous observations. Nat Commun 12:7309.

Hauck J, Gregor L, Nissen C, Patara L, Hague M, Mongwe P, Bushinsky S, Doney S, Gruber N, Le Quéré C, Manizza M, Mazloff M, Monteiro P, Terhaar J (2023) The Southern Ocean carbon cycle 1985-2018: Mean, seasonal cycle, trends and storage.

Hellmer HH, Holtappels M (2021) The Expedition PS124 of the Research Vessel POLARSTERN to the southern Weddell Sea in 2021. Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung; Bremerhaven, Germany.

Priest T, von Appen W-J, Oldenburg E, Popa O, Torres-Valdés S, Bienhold C, Metfies K, Boulton W, Mock T, Fuchs B, Amann R, Boetius A, Wietz M (2023) Atlantic water influx and sea-ice cover drive taxonomic and functional shifts in Arctic marine bacterial communities. ISME J 17:1612–1625.

Wietz M, Bienhold C, Metfies K, Torres-Valdés S, von Appen W-J, Salter I, Boetius A (2021) The polar night shift: seasonal dynamics and drivers of Arctic Ocean microbiomes revealed by autonomous sampling. ISME Commun 1:76.

5. ICEFISH-1 WEDDELL SEA ICE FISH STUDY

Autun Purser*[1], Lisa Chakrabarti[2], Chiara Papetti[3],	[1]DE.AWI
Pedro Costa Rodrigues Furtado[4]	[2]UK.NOTTING
not on board: Ulrich Hoge[1], Daniel Turner[4]	[3]IT.UNIPD
*autun.purser@awi.de	[4]COM.BBC

Grant-No. AWI_PS146_04

Outline

In Feburary 2021 *Polarstern* discovered the largest icefish brooding colony yet discovered on Earth (Purser et al. 2022a). During four deployments with the Ocean Floor Observation and Bathymetry System (OFOBS) (Purser et al. 2019) this colony was found to consist of at least 60 million *Neopagetopsis ionah* icefish, the majority of which were observed actively guarding eggs in nests across an area of at least 240 km^2 of the Filchner Trough eastern flank, in the Weddell Sea (Purser et al. 2022a, 2022b).

Objectives

The discovery in 2021 of the *Neopagetopsis ionah* colony presented for scientific study a potentially unique ecosystem, deep below the Antarctic ice, representing a locally high biomass (at least during the reproductive period of *N. ionah*) and one supporting the case and ongoing debate aimed at establishing a Marine Protected Area across the region (Teschke et al. 2021). With this in mind, the main aims of the multi-disciplinary 'ICEFISH-1' secondary user group are:

- Establish the southern extent of the Neopagetopsis ionah Weddell Sea egg brooding colony.
- Collect a limited number of N. ionah icefish for physiology, biochemistry and genetics studies.
- Carry out high resolution *in-situ* filming of nesting N. ionah and other ecosystem fauna.
- With other onboard participants, recover image and environmental data from a mooring array placed within the N. ionah colony and deploy new time series cameras to observe fish activity over the next 2-5 years.

Work at sea

Work at sea will comprise four categories of activity:

Firstly, the OFOBS towed camera and sidescan system will be deployed with additional high resolution cameras integrated to a) carry out high resolution filming of the activity within the *N. ionah* brooding colony and b) to be deployed at two locations south of the known colony area, to try to establish the southern extent of the nesting colony.

Secondly, the OFOBS will be equipped with a sampling net and used to directly sample, via videofeed, live *N. ionah* fish and fish eggs. This sampling will be carried out by gently lowering the OFOBS and under camera net to the seafloor under slow speed, to directly scoop up the target fish and eggs.

Thirdly, these fish and egg samples will then be investigated in the laboratory onboard. From the fish, the sex, weight, and reproductive state will be assessed. Mitochondrial physiology and sensitive respirometry will be recorded at different temperatures in tissue samples. Eggs will be cultured at different temperatures and their oxygen consumption measured. Muscle tissues will be used to generate primary cell cultures for experimental analyses on return to shore. From the eggs and fish, varied tissue samples will be collected for developmental, genetic connectivity and egg laying behavioural analysis by on-shore partners. Voucher specimens of fish and eggs will be collected for delivery to appropriate physical archives. A water sampler will also be fitted onto the OFOSB for environmental DNA (eDNA) collection and for analysis of bottom waters on-shore.

Fourthly, time-series cameras deployed during the PS124 expedition within the brooding colony will be recovered and any photographs taken analysed. Subsequent to this retrieval, a new camera and lighting array, based on the AWI 'PlasPi' cameras developed for low-cost, low-power time series use (Purser et al. 2020) will be deployed within the nesting colony to collect images twice a day for the 2-5 years following deployment.

Expected results

The key results expected from this work will be a spatial plan of the extent of the brooding colony within the Filchner Tough, Weddell Sea, for use in spatial planning in the future, and to inform further on the environmental factors which may determine the optimum brooding locations for *N. ionah*.

The physical samples of eggs and fish, though limited in number, are expected to yield much new information on physiology, reproductive behaviour, connectivity and genetics of this species, at the least, and the detailed study of the physiology and biochemistry of these poorly sampled haemoglobin-free species will likely expand our understanding of this approach to oxygen transport within large fauna considerably. Tissue and eDNA samples will help elucidate some of the outstanding questions on the connectivity of this species.

Numerous samples will be collected for subsequent delivery to on-shore researchers to further inform on this species and ecosystem.

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 expedition 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).

Proteomics datasets will be deposited in the MassIVE repository (https://massive.ucsd.edu/). Transcriptomics and geonomic datasets will be deposited in the Sequence Read Archive – SRA (https://www.ncbi.nlm.nih.gov/sra) which are readily accessed through GenBank platforms at NCBI. Submission of biological data to these public repositories will be made at time of first publication.

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

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

In all publications based on this expedition, the **Grant No. AWI_PS146_04** 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.

References

Purser A, Marcon Y, Dreutter S, Hoge U, Sablotney B, Hehemann L, Lemburg J, Dorschel B, Biebow H, Boetius A (2019) Ocean Floor Observation and Bathymetry System (OFOBS): A new towed camera/sonar system for deep sea habitat surveys. IEEE Journal of Oceanic Engineering 44:87-99. https://doi.org/10.1109/JOE.2018.2794095

Purser A, Hoge U, Lemburg J, Bodur Y, Schiller E, Ludszuweit J, Greinert J, Dreutter S, Dorschel B, Wenzhoefer F (2020) PlasPi Marine Cameras: Open-source, affordable camera systems for time series marine studies. HardwareX 7: e00102. https://doi.org/10.1098/rsos.182053

Purser A, Hehemann L, Boehringer L, Tippenhauer S, Wege M, Bornemann H, Pineda-Metz SEA, Flintrop CM, Koch F, Hellmer HH, Burkhardt-Holm P, Janout M, Werner E, Glemser B, Balaguer J, Rogge A, Holtappels M, Wenzhoefer F (2022a) A vast icefish breeding colony discovered in the Antarctic. Current Biology 32:842-850. https://doi.org/10.1016/j.cub.2021.12.022

Purser A, Hehemann L, Boehringer L, Werner E, Pineda-Metz SEA, Vignes L, Nordhausen A, Holtappels M, Wenzhoefer F (2022b) A vast icefish breeding colony discovered in the Antarctic. Earth System Science Data 14:3635-3648. https://doi.org/10.5194/essd-14-3635-2022

Teschke K, Brtnik P, Hain S, Herata H, Liebschner A, Pehlke H, Brey T (2021) Planning marine protected areas under the CCAMLR regime – The case of the Weddell Sea (Antarctica). Marine Policy 124:104370. https://doi.org/10.1016/j.marpol.2020.104370

6. SEA ICE PHYSICS AND BIOLOGY

Stefanie Arndt*[1,2], Daria Paul[1], Jan Rohde[1], Klaus Meiners[3]
*stefanie.arndt@awi.de

[1]DE.AWI
[2]DE.UNI-Hamburg
[3]AAD

Grant-No. AWI_PS_146_05

Objectives

Antarctic sea ice has shown complex variability, with a slight increase until 2016 followed by a marked decline, especially in the Weddell Sea (Purich and Doddridge, 2023; Turner et al., 2022). While the IPCC reports no significant trend from 1979 to 2020 (Masson-Delmonte et al., 2021), recent studies link this variability to atmospheric and oceanic processes, including Southern Annular Mode (SAM) anomalies (Francis et al., 2020; Schlosser et al., 2018). These changes have contributed to warmer air, enhanced cloud-radiation feedbacks, and stronger heat fluxes into the ice (Francis et al., 2020).

Sea ice loss has been further amplified by atmosphere-ocean interactions that increase heat absorption in the upper ocean (Meehl et al., 2019; Turner et al., 2020). However, the quantitative role of these processes in sea ice dynamics remains unclear, and better understanding is essential for accurate climate predictions. Observational data on sea ice thickness remain limited due to uncertainties in satellite measurements (e.g., Kacimi and Kwok, 2024), and models often fail to replicate observed trends, a discrepancy referred to as the “sea ice paradox” (Schneider and Deser, 2018).

Sea ice growth is driven by both thermodynamic and dynamic processes, with interactions between atmospheric heat fluxes and ocean currents shaping its thickness distribution (Haas, 2017; Holland and Kwok, 2012). Furthermore, snow-derived meteoric ice (e.g., Arndt et al., 2021) adds complexity to ice growth, introducing uncertainties in snow depth and thickness estimates that affect satellite and sea ice model retrievals (Arndt, 2022; Arndt et al., 2024). These uncertainties emphasize the need for more *in-situ* observations, particularly in key regions like the Ross and Weddell Seas (Mackie et al., 2020; Rack et al., 2021).

Furthermore, the Weddell Sea hosts a diverse ecosystem which is significantly relying on sea ice associated carbon production (Vernet et al., 2019). Nearly 50% of the annual Antarctic sea ice primary production (15.8 Tg C) is produced in the Weddell Sea and within the Weddell Sea particular the eastern margin is one of the most productive regions (Arrigo, 2014). Particularly in this region we witness so-called surface biota communities, which result from flooding and internal snowmelt processes. One consequence of downward heat flux and snow thaw is the percolation of melt water to the snow-ice interface and the formation of gap layers, continuous or highly porous layers in the upper ice filled with seawater or slush and high concentrations of algae and other micro-organisms (e.g., Haas et al., 2001; Kattner et al., 2004). In these habitats, we find a strong accumulation of organic compounds (Meiners et al., 2009). Nevertheless, due to the patchy distribution of the sea ice biota both horizontally and vertically, it is still difficult to obtain accurate estimates (Meiners et al., 2017; Meiners et al., 2012). The dissolved and particulate components from the ice can be transferred from the surface to the deep layers and can significantly affect the underlying water column.

The project "Summer Weddell Sea Ice and Snow Regimes" (SWISS) aims to address all the outlined research gaps by observing and quantifying the thickness distribution of different ice regimes in the Weddell Sea. It will also assess snow properties and their impact on sea ice changes, as well as establish connections between changes in snow and ice properties and the sea ice ecosystem. In the planned research region of the SWISS project, we expect a widespread occurrence of gap layers, which have rarely been sampled with regard to ice thickness, biodiversity, biomass, dissolved substances and other biogeochemical processes.

Work at sea

Helicopter-based ice thickness surveys

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

Snow and ice sampling

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

- Snow pit analysis of stratigraphy and density, salinity, etc.
- Snow micro-penetrometer profiles of ice hardness, density, and stratigraphy.
- Ground-EM measurements of ice thickness
- Surface cores of the snow, superimposed ice, gap layer system
- Water and biological and biogeochemical sampling of sea ice, the gap layer and under ice environment

Ice-tethered platforms (buoys)

A set of autonomous ice tethered platforms (buoys) will be deployed to monitor the seasonal and inter-annual variability of sea ice parameters, such as sea ice drift and deformation as well as sea ice thickness, snow depth, and the sea surface radiation budget.

On board

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

Preliminary (expected) results

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

- Observe the thickness distribution of different ice regimes in different ice classes in the Weddell Sea, i.e., seasonal sea ice in the southeast and perennial sea ice in the northwest, in relation to their deformation history and oceanic heat regimes.
- Deriving long-term sea ice and snow thickness changes by comparing the results from the SWISS project to previous expeditions to the same region.
- Quantification of snow properties, degree of snow metamorphism and proportion of snow-to-ice conversion to assess snow melt intensity and associated potential detection of Antarctic sea ice change through atmospheric parameters as, e.g., the surface energy budget.
- Identify a direct link between seasonal and interannual changes in snow and ice properties on the one hand, and gap layer communities and sea ice biogeochemical properties on the other.

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 expedition 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.

Buoy data will be available in near-real time through the online portal www.meereisportal.de, and will be embedded into different international data bases, as through the International Program for Antarctic Buoys (IPAB). End the end of their life time, the buoy data will be quality checked and will be stored in PANGAEA.

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

In all publications based on this expedition, the **Grant No. AWI_PS146_05** 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.

References

Arndt S (2022) Sensitivity of Sea Ice Growth to Snow Properties in Opposing Regions of the Weddell Sea in Late Summer. Geophysical Research Letters 49: e2022GL099653. http://dx.doi.org/10.1029/2022GL099653

Arndt S, Maaß N, Rossmann L, and Nicolaus M (2024) From snow accumulation to snow depth distributions by quantifying meteoric ice fractions in the Weddell Sea. The Cryosphere 18: 2001-2015. http://dx.doi.org/10.5194/tc-18-2001-2024

Arndt S, Haas C, Meyer H, Peeken I, and Krumpen T (2021) Recent observations of superimposed ice and snow ice on sea ice in the northwestern Weddell Sea. The Cryosphere 15: 4165-4178. http://dx.doi.org/10.5194/tc-15-4165-2021

Arrigo KR (2014) Sea ice ecosystems. Annual Review of Marine Science 6: 439-467. http://dx.doi.org/10.1146/annurev-ma-7-120414-100001

Francis D, Mattingly KS, Temimi M, Massom R, and Heil P (2020) On the crucial role of atmospheric rivers in the two major Weddell Polynya events in 1973 and 2017 in Antarctica. Science Advances 6: eabc2695. http://dx.doi.org/10.1126/sciadv.abc2695

Haas C (2017) Sea ice thickness distribution. In: Sea ice. 3rd Edition, edited by: Thomas, D., Wiley-Blackwell, New York (USA) & Oxford (UK), 42-64

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

Holland PR and Kwok R (2012) Wind-driven trends in Antarctic sea-ice drift. Nature Geoscience 5: 872-875. http://dx.doi.org/10.1038/ngeo1627

Kacimi S and Kwok R (2024) Two Decades of Arctic Sea-Ice Thickness from Satellite Altimeters: Retrieval Approaches and Record of Changes (2003–2023). Remote Sensing 16: 2983. http://dx.doi.org/10.3390/rs16162983

Kattner G, Thomas DN, Haas C, Kennedy H, and Dieckmann GS (2004) Surface ice and gap layers in Antarctic sea ice: highly productive habitats. Marine Ecology Progress Series 277: 1-12. http://dx.doi.org/10.3354/meps277001

Mackie S, Langhorne PJ, Heorton HD, Smith IJ, Feltham DL, and Schroeder D (2020) Sea ice formation in a coupled climate model including grease ice. Journal of Advances in Modeling Earth Systems 12: e2020MS002103. http://dx.doi.org/10.1029/2020MS002103

Masson-Delmonte V, Zhai P, Pirani A, Connors S, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis M, Huang K, Leitzell E, Lonnoy JBRM, T.K., Maycock T, Waterfield O, Yelekçi RY, and Zhou Be (2021) IPCC 2021: Climate Change 2021: The Physical Science Basis: Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

Meehl GA, Arblaster JM, Chung CT, Holland MM, DuVivier A, Thompson L, Yang D, and Bitz CM (2019) Sustained ocean changes contributed to sudden Antarctic sea ice retreat in late 2016. Nature Communications 10: 1-9. http://dx.doi.org/10.1038/s41467-018-07865-9

Meiners K, Papadimitriou S, Thomas D, Norman L, and Dieckmann G (2009) Biogeochemical conditions and ice algal photosynthetic parameters in Weddell Sea ice during early spring. Polar Biology 32: 1055-1065. http://dx.doi.org/10.1007/s00300-009-0605-6

Meiners K, Arndt S, Bestley S, Krumpen T, Ricker R, Milnes M, Newbery K, Freier U, Jarman S, and King R (2017) Antarctic pack ice algal distribution: Floe-scale spatial variability and predictability from physical parameters. Geophysical Research Letters 44: 7382-7390. http://dx.doi.org/10.1002/2017GL074346

Meiners KM, Vancoppenolle M, Thanassekos S, Dieckmann GS, Thomas DN, Tison JL, Arrigo KR, Garrison DL, McMinn A, Lannuzel D, van der Merwe P, Swadling KM, Smith WO, Melnikov I, and Raymond B (2012) Chlorophyll a in Antarctic sea ice from historical ice core data. Geophysical Research Letters 39: 10.1029/2012gl053478

Purich A and Doddridge EW (2023) Record low Antarctic sea ice coverage indicates a new sea ice state. Communications Earth & Environment 4: 314. http://dx.doi.org/10.1038/s43247-023-00961-9

Rack W, Price D, Haas C, Langhorne PJ, and Leonard GH (2021) Sea Ice Thickness in the Western Ross Sea. Geophysical Research Letters 48: e2020GL090866. http://dx.doi.org/10.1029/2020GL090866

Schlosser, Haumann FA, and Raphael MN (2018) Atmospheric influences on the anomalous 2016 Antarctic sea ice decay. Cryosphere 12: 1103-1119. http://dx.doi.org/10.5194/tc-12-1103-2018

Schneider DP and Deser C (2018) Tropically driven and externally forced patterns of Antarctic sea ice change: Reconciling observed and modeled trends. Climate Dynamics 50: 4599-4618. http://dx.doi.org/10.1007/s00382-017-3893-5

Turner J, Holmes C, Caton Harrison T, Phillips T, Jena B, Reeves-Francois T, Fogt R, Thomas ER, and Bajish C (2022) Record low Antarctic sea ice cover in February 2022. Geophysical Research Letters 49: e2022GL098904. http://dx.doi.org/10.1029/2022GL098904

Turner J, Guarino MV, Arnatt J, Jena B, Marshall GJ, Phillips T, Bajish C, Clem K, Wang Z, and Andersson T (2020) Recent decrease of summer sea ice in the Weddell Sea, Antarctica. Geophysical Research Letters 47: 1-11. http://dx.doi.org/10.1029/2020GL087127

Vernet M, Geibert W, Hoppema M, Brown PJ, Haas C, Hellmer H, Jokat W, Jullion L, Mazloff M, and Bakker D (2019) The Weddell Gyre, Southern Ocean: present knowledge and future challenges. Rev Geophys 57: 623-708. http://dx.doi.org/10.1029/2018RG000604

7. COMA2: NICHE SHAPING MOLECULES OF THE CRYOSPHERE

Jan Tebben[1*], Zibusiso Mayibongwe Buthelezi[2], Markus Janout[1], Olaf Boebel[1]
not on board: Boris Koch[1], Thulani Makhalanyane[3], Stéphane Pesant[4], Alessandro Tagliabue[5], Magdalena Santana-Casiano[6]
*jan.tebben@awi.de

[1]DE.AWI
[2]ZA.Mandela
[3]ZA.SU
[4]EMBL-EBI Cambridge
[5]UK.UNI-Liverpool-EOE
[6]ES.ULPGC

Grant-No. AWI_PS_146_01

Outline

Freezing seawater phase-separates in ice crystals and saline brine. Sustained microalgal and bacterial growth in this ecological niche requires mechanisms that counteract strong gradients across the ice/water interface such as unphysiological temperature, ionic strengths, pH and pressure. Antarctic psychrophilic microorganisms employ several metabolic strategies to combat negative effects in this extreme environment such as cold-active enzymes, membrane fluidity, antifreeze and cold-shock proteins, intracellular cryoprotectants and adjusted metabolic rates. Microbial life in Antarctic sea-ice, however, is not only confronted with low-temperatures and tremendous gradients, but very rapid transitions from one extreme to another. Our understanding of the metabolic adaptations that govern microbial life in the cryosphere is still lacking, severely limiting our ability to predict the effect of warming on the highly adapted organisms in this habitat.

This project investigates the chemical drivers of microbial niche adaptation, and specifically the role of these metabolites in the relationship between ice algae and their associated bacterial community. It is prerequisite to characterize the role of mutualism in the temporal and spatial distribution of bacteria and microalgae to ultimately understand primary production and carbon cycling of this region.

Objectives

In general, this project within the PS146 HAFOS campaign aims to test the co-adaptation of Antarctic marine bacteria to rapid environmental changes at the molecular level. The PS146 expedition will follow up from sampling that was conducted during the earlier HAFOS campaign from March to April 2022 (PS129). This expedition covered the same transect from the Prime Meridian to the *Neumayer Station III* and then across the Weddell Sea between Kapp Norvegia and the tip of the Antarctic Peninsula with two excursions to the south (Hoppema 2023). The PS129 team observed and sampled hydrography, nutrients, dissolved oxygen, carbon dioxide, dissolved and particulate organic carbon, eDNA and isolated live bacterial and microalgal strains (Hoppema 2023).

Microbial Biodiversity Hypotheses: (1) Local physico-chemical processes such as temperature and salinity gradients across the water column and ice-water interface control the co-inhabitation of psychrophilic bacteria and microalgae. (2) The co-adaptation of ice-algae and associated bacteria is reflected in their ability to produce cold-adapted metabolites such as cold-shock proteins, antifreeze proteins (AFPs) or recrystallization inhibition proteins (RIPs).

Microbial Biodiversity objective: We will utilize a sequencing approach to characterize how the microbial community is dependent on the formation and distribution of temperature gradients and the sea-ice. It is likely that many of the organisms isolated during the ice-algal bloom are not only co-occurring but co-dependent. Therefore, our data will generate a baseline understanding in this under-sampled region as well inform predictions on responses to future climate scenarios.

Mutualistic Cold-Adaptation Hypothesis: Chemical drivers of niche manipulation (e.g., AFPs, RIPs) are ubiquitous among sea-ice associated microalgae and bacteria. *Mutualistic Cold-Adaptation Objective:* The objective of this project is to isolate and cultivate cold-adapted diatoms and bacteria in order to (later) structurally characterize their chemical drivers of mutualistic relationships. Additionally, the project will sample, isolate and quantify molecules *in situ*. A consequential objective is then to correlate the genetic diversity of bacteria and phytoplankton (e.g., Bucklin et al. 2016, Gorsky et al. 2019) with aggregation rates and environmental parameters (such as, DMSP, iron, salinity and temperature).

Work at sea

Water column and ice sampling: Water samples will be taken from the CTD or melted ice samples and filtered to concentrate the particulate and dissolved organic matter as well as to characterize the genetic diversity (DNA barcoding). Specifically, 20 L each for a maximum of 3 water depths per station will be sequentially filtered over 0.2 µm, 3 µm and 0.8 µm to characterize the phytoplankton and bacterioplakton community. Additionally, both phytoplankton species and clonal lines of bacterial strains will be isolated from single cells on board to be used in co-inoculation experiments in the home laboratories. Water from the CTD (1 L, 12 depths per station maximum) will also be divided for Fe^{3+} (0.25 L, 0.2 µm filtered over Sartobran 300), live bacterial cultures (15 mL), nutrients (20 mL), dissolved organic carbon (DOC, 20 mL), fluorescence (FL, 20 mL) analysis, particulate organic carbon (POC, 2 L), and DOM composition (500 mL, Koch et al. 2014) (Tab. 7.1).

Tab. 7.1: Sample types taken from the CTD rosette

Parameter	Treatment	Sample volume	Storage container	Storage condition
DOC	GF/F filtered, sampling under laminar flow in clean room container	20 mL	HDPE bottle	Frozen -20°C
SPE-DOM	GF/F filtered, acidified	500 mL	ppl resin/PP cartridge	Frozen -20°C
Fluorescence	GF/F filtered	20 mL	HDPE bottle	Frozen -20°C
Nutrients	Unfiltered, sampling under laminar flow in clean room container	20 mL	HDPE bottle	Direct analysis
Bacterial culture	Unfiltered	15 mL	Sterile falcon tube	Agar plating
microbiome genomics	Unfiltered, 3 µm, 0.2 µm filtration. $FeCl_3$ precipitate (12 h) filtered onto 0.8 µm	20 L	5 mL cryotube	Snap frozen in liquid N_2, then -80°C
Fe(3+)	0.2 µm filtration	250 mL	LDPE bottle	Frozen -20°C
DMSP	Unfiltered, acidified	12 mL	Glas vial	0°C

Expected results

We expect distinct bacterial and phytoplankton communities across the temperature gradient of the Prime meridian as well as Weddell Sea (Fig. 7.1). We also expect seasonal differences of the Phyto-, Bakterio-, and Virioplankton communities in comparison to those observed during the PS129 expedition in the Austral autumn in 2022. Additionally, we expect differences to the rate of deep-water formation and therefore transport of organic matter into greater depths.

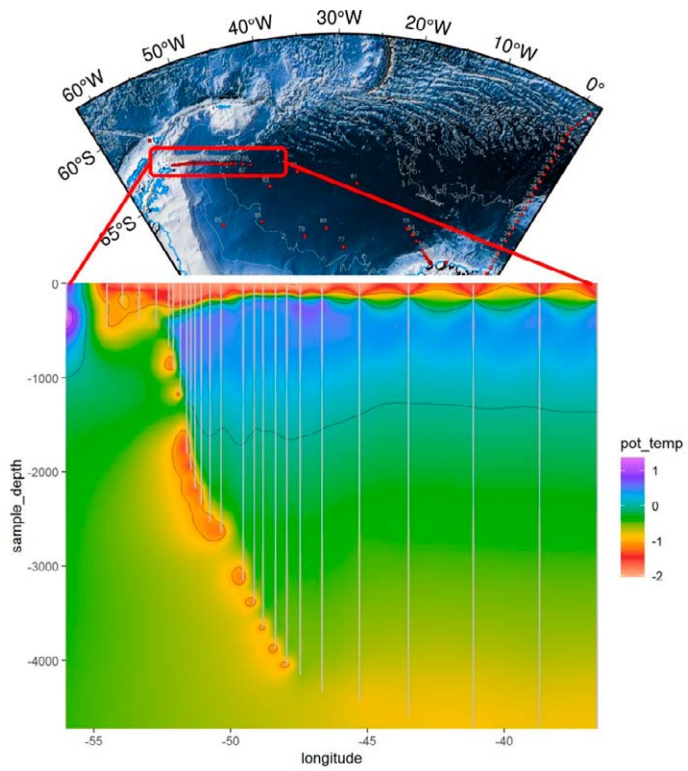


Fig. 7.1: The potential temperature across the Weddell Sea from the HAFOS PS129 expedition in 2022 shows low temperatures at the surface and the clear bottom-water formation.

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 expedition at the latest. By default, the CC-BY license will be applied.

Molecular data (DNA sequences) 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 6, Subtopics 6.1 and 6.3.

In all publications based on this expedition, the **Grant No. AWI_PS146_01** 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.

References

Bucklin A, Lindeque PK, Rodriguez-Ezpeleta N, Albaina A, Lehtiniemi M (2016) Metabarcoding of marine zooplankton: prospects, progress and pitfalls. Journal of Plankton Research, 38, 393-400.

Koch BP, Kattner G, Witt M, Passow U (2014) Molecular insights into the microbial formation of marine dissolved organic matter: recalcitrant or labile? Biogeosciences, 11, 4173-4190.

Gorsky G, et al. (2019) Expanding Tara Oceans Protocols for Underway, Ecosystemic Sampling of the Ocean-Atmosphere Interface During Tara Pacific Expedition (2016–2018). Frontiers in Marine Science, 6, 750.

8. BATHYMETRY

Annie Lemire[2], Paula Allertseder[3], Miao Fan[4]
not on board: Boris Dorschel*[1], Simon Dreutter[1]
*boris.dorschel@awi.de

[1]DE.AWI
[2]DE.UNI-Bremen
[3]DE.UNI-Potsdam
[4]CN.NMDIS

Grant-No. AWI_PS146_06

Objectives

Accurate knowledge of the seafloor topography, hence high-resolution bathymetry data, is a basic key information and necessary to understand many marine processes. It is of particular importance for the interpretation of scientific data in a spatial context. Bathymetry and from it derived topography, are fundamental parameters of importance for understanding many marine processes. For example, the flow of water masses across the continental shelves towards and below ice shelves follows pathways constrained by topography. In this way, the topography affects the oceanography.

While world bathymetric maps give the impression of a detailed knowledge of worldwide seafloor topography, most of the world's ocean floor remains unmapped by hydroacoustic systems. In these areas, bathymetry is modelled using satellite altimetry with a corresponding low resolution. Satellite-altimetry derived bathymetry therefore lack the resolution necessary to resolve small- to meso-scale geomorphological features (e.g. trough axes, canyons and sills). Ship-borne multibeam data provide bathymetric information at a resolution sufficient to resolve these features and enable site selection for other scientific working groups on board.

Furthermore, the collection of underway data during PS146 will contribute to the bathymetry data archive at the AWI and thus to bathymetric world datasets such as GEBCO (General Bathymetric Chart of the Ocean).

Work at sea

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

Preliminary (expected) results

Expected results will consist of high-resolution seabed maps along the cruise track and from the target research sites. The bathymetric data will be analyzed to obtain geomorphological information of the research area. The expected results aim towards an improved bathymetric model as key base dataset to support research in the study area.

Data management

Bathymetric 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.

Furthermore, the data will be included in regional data compilations such as IBCSO (International Bathymetric Chart of the Southern Ocean) and provided to the Nippon Foundation – GEBCO Seabed 2030 Project.

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

In all publications based on this expedition, the **Grant No. AWI_PS_146_06** 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.

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	**Address**
on board	
AU.AAD	Australian Antarctic Division Channel Highway 203 7050 Kingston Australien
CN.NMDIS	National Marine Data and Information Service No. 93 Liuwei Road, Hedong District 300171 Tianjin China
COM.BBC	British Broadcasting Corporation Broadcasting House Peel Wing Portland Place W1A 1AA London Vereinigtes Königreich
DE.AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
DE.DRF	DRF Luftrettung gAG Laval Avenue E312 77836 Rheinmünster Deutschland
DE.DWD	Deutscher Wetterdienst Seewetteramt Bernhard Nocht Str. 76 20359 Hamburg Germany
DE.NHC	Northern HeliCopter GmbH Gorch-Fock-Str., 103 26721 Emden Deutschland
DE.UNI-Bremen	Universität Bremen Bibliothekstrasse 1 28359 Bremen Deutschland
DE.UNI-Hamburg	Universität Hamburg Bundesstraße 55 20146Hamburg Deutschland

Affiliation	**Address**
on board	
DE.UNI-Oldenburg	Carl von Ossietzky Universität Oldenburg Carl-von-Ossietzky-Strasse 9-13 26132 Oldenburg Deutschland
DE.UNI-Potsdam	Universität Potsdam Am Neuen Palais 10 14469 Potsdam Deutschland
FR.LOCEAN.UPMC	Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques 4 place Jussieu 75005 Paris Frankreich
IT.UNIPD	Universita Degli Studi Di Padova Via U. Bassi 58/b 35131 Padova Italien
NO.NORCE	NORCE Nygårdsgaten 112 Jahnebakken 5 5008 Bergen Norwegen
SE.GU	Göteborgs Universitet Universitet Platsen 1 405 30 Göteborg Schweden
UK.NOTTING	Sutton Bonington Campus SVMS LE12 5RD Nottingham Vereinigtes Königreich
UK.UC	University of Nottingham 20 Kirkwood Ave, Ilam 8041 Christchurch Neuseeland
ZA.Mandela	Nelson Mandela University University Way, Summerstrand 6031 Gqeberha Südafrika
ZA.Mandela	Nelson Mandela University JC Smuts Building, B Block, 3rd Floor, van der Byl 7600 Stellenbosch Südafrika

Not on board	
EMBL-EBI Cambridge	European Bioinformatics Institute Cambridge United Kingdom
ES.ULPGC	Universidad de Las Palmas de Gran Canaria, Las Palmas Spain
NO.UNI-Bergen	University of Bergen Bergen Norway
UK.UNI-Liverpool-EOE	University of Liverpool Liverpool United Kingdom:
ZA.UP	University of Pretoria Pretoria South Africa
ZA.SU	Stellenbosch University Stellenbosch South Africa

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
Allertseder	Paula Anna Franziska	DE.UNI-Potsdam	Student/in (Master)	andere Geowissenschaften
Arndt	Stefanie	DE.AWI	Wissenschaftler/in	Meteorologie
Aschenbeck	Lara Jane	DE.UNI-Bremen	Doktorand/in	Physik
Barz	Jakob	DE.AWI	Techniker/in	Chemie
Boebel	Olaf	DE.AWI	Wissenschaftler/in	Ozeanografie
Bornemann	Horst	DE.AWI	Wissenschaftler/in	Biologie
Brauer	Jens	DE.NHC	Pilot/in	Helikopter Service
Buthelezi	Zibusiso Mayibongwe	ZA.Mandela	Doktorand/in	Biologie
Chakrabarti	Lisa	UK.NOTTING	Wissenschaftler/in	Biologie
Fan	Miao	CN.NMDIS	Wissenschaftler/in	Geophysik
Forthaus	Fridjof	DE.AWI	Student/in (Bachelor)	Ingenieur-wissenschaften
Furtado Costa Rodrigues	Pedro	COM.BBC	Sonstige (z.B. Freiberufler/in oder Schüler/in)	Öffentlichkeitsarbeit
Hölemann	Jens	DE.AWI	Wissenschaftler/in	Ozeanografie
Holtappels	Moritz	DE.AWI	Wissenschaftler/in	Biologie
Huhn	Oliver	DE.UNI-Bremen	Wissenschaftler/in	Ozeanografie
Janout	Markus	DE.AWI	Wissenschaftler/in	Ozeanografie
Jouet	Ombeline Anna Paule Rose-Marie	DE.AWI	Doktorand/in	Ozeanografie
Jörss	Anna Maria	DE.AWI	Doktorand/in	Meteorologie
Le Chevère	Simone	DE.AWI	Doktorand/in	Ozeanografie
Lemire	Annie Catherine Juliette	DE.UNI-Bremen	Student/in (Master)	Geophysik
Losch	Martin	DE.AWI	Wissenschaftler/in	Ozeanografie
Meiners	Klaus	AU.AAD	Wissenschaftler/in	Biologie
Middleton	Leo	SE.GU	Wissenschaftler/in	Ozeanografie
Miehe	Kai	DE.DRF	Techniker/in	Helikopter Service
Monsees	Matthias Udo	DE.AWI	Techniker/in	Ozeanografie
Mosneron-Dupin	Cosme	FR.LOCEAN. UPMC	Doktorand/in	Ozeanografie
Olivier	Léa Lucie Alice	DE.AWI	Wissenschaftler/in	Ozeanografie
Østerhus	Svein	NO.NORCE	Wissenschaftler/in	Ozeanografie

Name/ Last name	**Vorname/ First name**	**Institut/ Institute**	**Beruf/ Profession**	**Fachrichtung/ Discipline**
Panter	Gabriel	DE.DRF	Techniker/in	Helikopter Service
Papetti	Chiara	IT.UNIPD	Wissenschaftler/in	Biologie
Paul	Daria	DE.AWI	Doktorand/in	Geophysik
Purser	Autun	DE.AWI	Wissenschaftler/in	Biologie
Robertson	Emma Renee	DE.AWI	Doktorand/in	Ozeanografie
Rogge	Andreas	DE.AWI	Wissenschaftler/in	Biologie
Rohde	Jan	DE.AWI	Ingenieur/in	Ingenieur-wissenschaften
Schaubensteiner	Stefan	DE.NHC	Pilot/in	Helikopter Service
Schröder	Henning	DE.AWI	Ingenieur/in	Ingenieur-wissenschaften
Spiesecke	Stefanie Daniela	DE.AWI	Ingenieur/in	Ozeanografie
Taylor	Krissy Anne	DE.AWI	Wissenschaftler/in	Ozeanografie
Tebben	Jan	DE.AWI	Wissenschaftler/in	Chemie
Tippenhauer	Sandra	DE.AWI	Wissenschaftler/in	Ozeanografie
Vargas Fonseca	Olga Alejandra	ZA.Mandela	Wissenschaftler/in	Biologie
Volkova	Valentina	DE.AWI	Doktorand/in	Ozeanografie
Wege	Mia	UK.UC	Wissenschaftler/in	Biologie
Welsch	Andreas	DE.UNI-Hamburg	Techniker/in	Ozeanografie
Wenzel	Anna Julia	DE.DWD	Wissenschaftler/in	Meteorologie
Wietz	Matthias	DE.UNI-Oldenburg	Wissenschaftler/in	Biologie
Woehle	Svenja Kathleen	DE.AWI	Doktorand/in	Ozeanografie
Zapponini	Martina	DE.AWI	Doktorand/in	Physik

A.3 SCHIFFSBESATZUNG / SHIP'S CREW PS146

No.	Position / Rank	Nachname / Last name	Vorname / First name
1	Master (P)	Schwarze	Stefan
2	Chief Mate (P)	Strauss	Erik
3	Chief Mate Cargo (P)	Eckenfels	Hannes
4	2nd Mate (P)	Heisterkamp	Ole Louca
5	2nd Mate (P)	Peine	Lutz
6	2nd Mate (P)	Weiß	Daniel
7	Ship's Doc	Guba	Klaus
8	Chief Engineer (P)	Ziemann	Olaf
9	2nd Engineer (P)	Farysch	Tim
10	2nd Engineer (P)	Krinfeld	Oleksandr
11	2nd Engineer (P)	Loske	Sven
12	Electrical Engineer – Communication (P)	Mueller	Andreas
13	Electrical Engineer (P)	Ejury	René
14	Electrical Engineer (P)	Krueger	Lars
15	Electrical Engineer (P)	Pommerencke	Bernd
16	Electrical Engineer (P)	Winter	Andreas
17	Bosun	Meier	Jan
18	FA/D	Buchholz	Joscha
19	FA/D	Decker	Jens
20	FA/D	Deutschbein	Felix Maximilian
21	FA/D	Knueppel	Timo
22	FA/D	Mahlmann	Oliver Karl-Heinz
23	FA/D	Moeller	Falko
24	FA/D	Rhau	Lars-Peter
25	FA/D	Schade	Tom
26	FA/D	Siemon	Leon Anton
27	FA/M	Buchholz	Karl
28	FA/M	Juszczyk	Michal

No.	Position / Rank	Nachname / Last name	Vorname / First name
29	FA/M	Schroeder	Paul
30	FA/M	Stubenrauch	Paula
31	FA/M	Toeben	Carlotta
32	Carp.	Keller	Juergen
33	FA/D (AB)	Niebuhr	Tim
34	Fitter / E	Probst	Lorenz
35	Cook	Skrzipale	Mitja
36	2./Cook	Fehrenbach	Martina
37	2./Cook	Loibl	Patrick
38	C/Stew.	Witusch	Petra Gertrud Ramona
39	Steward(ess) / Nurse	Ilk	Romy
40	2./Stew.	Chen	Jirong
41	2./Stew.	Chen	Quanlun
42	2./Stew.	Holl	Claudia
43	2./Stew.	Probst	Sabine
44	2./Stew.	Shi	Wubo
45	2./Stew.	Stocker	Eileen Sigourney