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

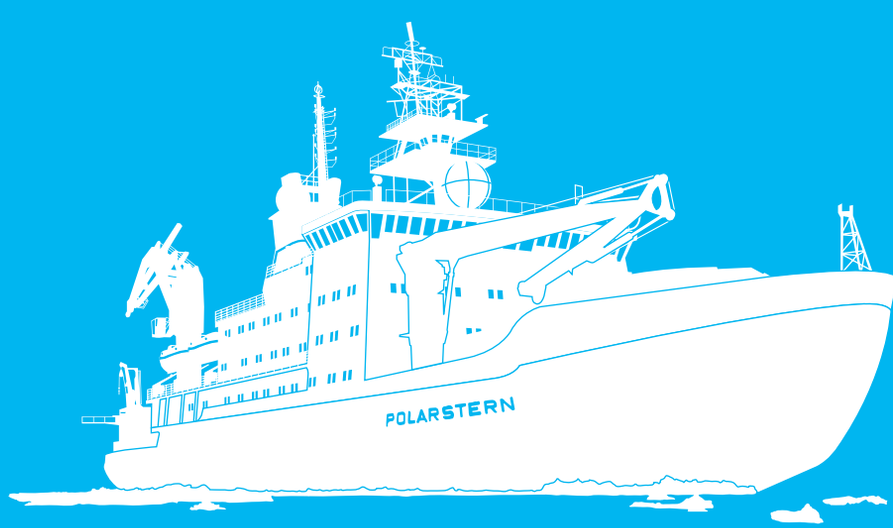
EXPEDITION PROGRAMME PS143/2

Polarstern

PS143/2
Tromsø – Tromsø
12 July 2024 – 06 August 2024

Coordinator: Ingo Schewe

Chief Scientist: Katja Metfies



HELMHOLTZ

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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.

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Contents

1. ÜBERBLICK UND EXPEDITIONSVERLAUF

Katja Metfies DE.AWI

Expedition PS143/2 des Forschungsschiffes *Polarstern* startet am 12. Juli 2024 mit dem Auslaufen in Tromsö. Das Untersuchungsgebiet zwischen Spitzbergen und Grönland, wo sich auch das Lanzeitobservatorium HAUSGARTEN (LTER HAUSGARTEN) befindet, wird nach etwa ~2-3 Tagen Transit erreicht sein. Ziel der Expedition ist es, die marine Biodiversität und klimarelevante Prozesse des arktischen Ozeans vor dem Hintergrund des Klimawandels genauer zu erfassen und verstehen zu können. Ein Großteil der geplanten Arbeiten und Projekte dieser Expedition dienen dem Austausch von Geräten und Installationen für die Fortführung der Langzeitbeobachtungen im Rahmen der Helmholtz Infrastruktur Initiative FRAM (Frontiers in Arctic Marine Monitoring). Darüber hinaus leisten die Arbeiten einen wichtigen Beitrag zum Langzeitobservatorium HAUSGARTEN, sowie zu weiteren nationalen und internationalen Projekten wie z.B. SIOS (Svalbard Integrated Observing System) und ICOS (Integrated Carbon Observation System), sowie den EU-Projekten Arctic PASSION, AtlantEco, oder OBAMA_NEXT. Dabei liegt der Schwerpunkt der Untersuchungen von PS143/2 in der Wassersäule. So werden auf verschiedenen Transekten hoch aufgelöste Untersuchungen physikalischer und biogeochemischer Prozesse in der oberen Wassersäule und der Tiefsee mittels geschleppter und autonomer Geräte gemacht, die neben den Arbeiten zur Fortführung der Stationsarbeiten im Rahmen des Langzeitsbeobachtungsprogramms durchgeführt werden. Untersuchungen der Meereisbiota werden dieses Beobachtungs-programm ergänzen, um die Rolle der kryo-pelagischen Kopplung im Ökosystem der Framstraße zu untersuchen.

Insgesamt stehen die Ziele dieser Expedition in unmittelbarem Zusammenhang mit der Umsetzung des Forschungsprogramms „Changing Earth – Sustaining our Future“ des Forschungsbereichs „Erde und Umwelt“ der Helmholtz-Gemeinschaft, an dem das AWI zusammen mit sechs weiteren Helmholtz-Zentren beteiligt ist. Hier trägt die Expedition direkt zur Umsetzung der Forschungsziele von Topic 2 „Ocean and cryosphere in climate“ und Topic 6 “Marine and Polar Life: Sustaining Biodiversity, Biotic Interactions and Biogeochemical Functions” bei. In Topic 6 (Subtopics 6.1 “Future ecosystem functionality” und 6.3 “The future biological carbon pump”) werden die mit steigenden Wassertemperaturen und dem Rückgang des Meereises verbundenen Veränderungen im Ökosystem im Pelagial und im tiefen Ozean ermittelt und quantifiziert, sowie Rückkopplungsprozesse auf ozeanographische Prozesse untersucht. Die Untersuchungen beinhalten die Identifizierung räumlicher und zeitlicher Entwicklungen in der Funktion ausgewählter Plankton- und Benthos-Gemeinschaften, sowie den Aufbau eines umfassenden Repositoriums für Beobachtungsdaten.

Im Rahmen der Expedition werden multidisziplinäre Untersuchungen durchgeführt, die einen Fokus auf die Wassersäule haben, aber an einzelnen Stationen fast alle Bereiche des marinen Ökosystems abdecken. Ausgewählte Stationen des LTER HAUSGARTEN werden nach ihrer Untersuchung auf PS143/1 auf PS143/2 nochmals besucht, um die kurzfristige Entwicklung des Systems zu untersuchen. In der Wassersäule werden Untersuchungen zur Biodiversität, Biomasse und Verteilung verschiedener Plankton-Gruppen und der zugehörigen biogeochemischen Parameter durchgeführt. Dabei werden klassische Mikroskopie und biogeochemische Analytik parallel zu modernsten optischen und molekulargenetischen Hochdurchsatzmethoden eingesetzt. Komplementär zu den Untersuchungen in der Wassersäule werden Untersuchungen der Biodiversität, Biomasse und Verteilung von benthischen Organismen verschiedener Größenklassen durchgeführt. Die Messungen

biologischer und biogeochemischer Parameter im Pelagial und im Benthos der Fram Straße werden durch Messungen ozeanographischer und chemischer Parameter ergänzt. Zusammen mit Studien zu Mechanismen und Umfang des vertikalen Exports organischen Materials in der Wassersäule sollen die Erkenntnisse und Daten aus den pelagischen und benthischen Langzeitbeobachtungen zu einem besseren Verständnis des Kohlenstoffflusses und möglicher klimawandelbedinter Veränderungen im arktischen Ozean beitragen. Die Umsetzung der wissenschaftlichen Ziele dieser Expedition umfasst den Einsatz verschiedener gezielt eingesetzter optischer Beobachtungssysteme und Probennehmer für pelagische und benthische Studien, sowie die Aufnahme und das Ausbringen von Verankerungen, die mit Sedimentfallen, Sensorsystemen oder automatischen Probennehmern bestückt sind. Darüber hinaus ist der Einsatz eines Autonomen Unterwasserfahrzeugs (AUV) und Gleitern geplant. Nach Ablegen in Tromsö werden parallel zum vorher beschriebenen Arbeitsprogramm kontinuierlich Proben aus der unteren Atmosphäre genommen um die Konzentrationen von Ammoniak- und Ammonium der Atmosphäre im Rahmen des italienischen Projekts GIAIA zu bestimmen.

Die Stationsarbeiten werden im östlichen Teil des LTER HAUSGARTEN beginnen, um dann zunächst in der westlichen Fram Strasse fortgeführt und anschließend im nördlichen Teil des Langzeitobservatoriums beendet zu werden. Nach Abschluss der Stationsarbeiten wird die Expedition nach einem kürzeren Transit von ~ 2-3 Tagen am 06.08.2024 mit dem Einlaufen in Tromsö enden.

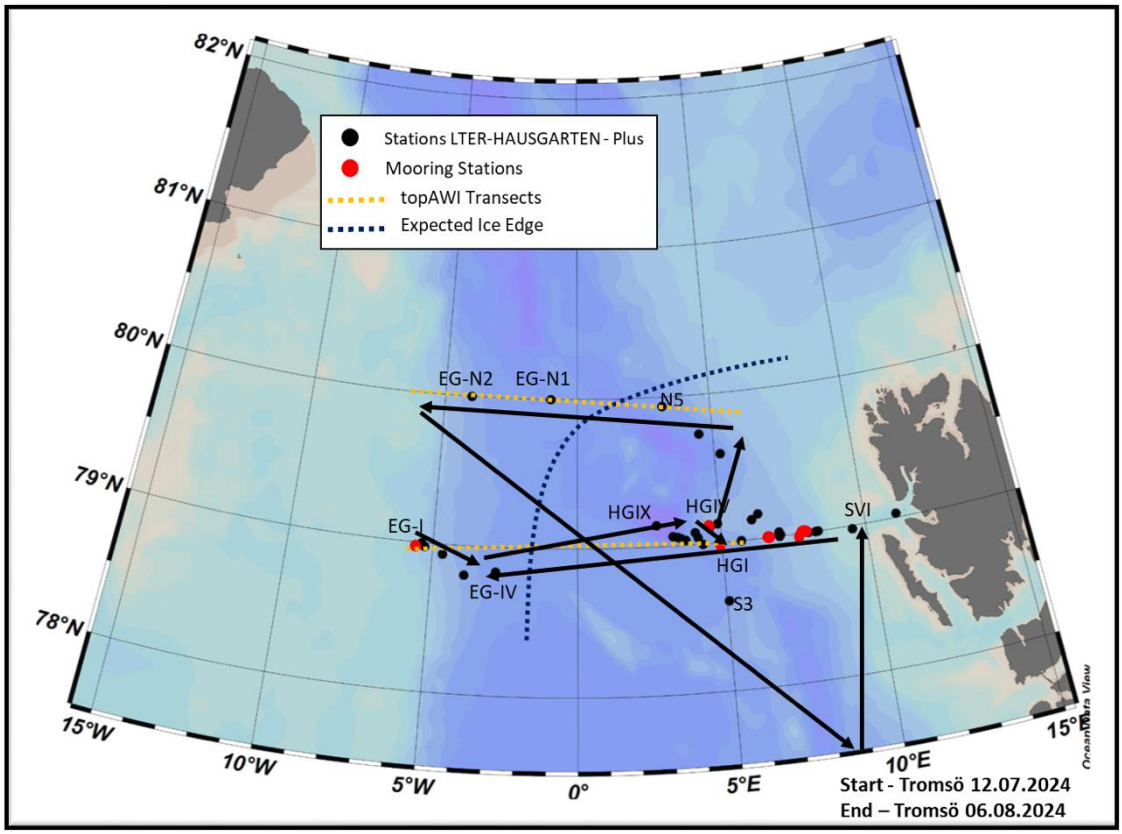

Fig. 1.1: Map illustrating the preliminary cruise track and permanent stations of the long-term observatory HAUSGARTEN in Fram Strait.

SUMMARY AND ITINERARY

Expedition PS143/2 of RV *Polarstern* departs from Tromsø on July 12, 2024. The study area between Spitsbergen and Greenland, where the HAUSGARTEN long-term observatory (LTER HAUSGARTEN) is located, will be reached after about ~2-3 days of transit. The aim of the expedition is to assess and understand patterns of marine biodiversity and climate-relevant processes of the Arctic Ocean more precisely against prevailing climate change. Much of the work and projects planned for this expedition will facilitate replacement of equipment and installations for the continuation of year-round long-term observations as part of the Helmholtz Infrastructure Initiative FRAM (Frontiers in Arctic Marine Monitoring). In addition, the work contributes to the long-term observatory HAUSGARTEN, as well as to other national and international projects such as SIOS (Svalbard Integrated Observing System) and ICOS (Integrated Carbon Observation System), and the EU-Projects Arctic PASSION, AtlantEco, or OBAMA_NEXT. The work focuses on supporting investigations in the water column. In addition to the work at long-term stations, high-resolution surveys of physical and biogeochemical processes in the upper water column and the deep sea will be carried out on transects using towed and autonomous devices. Studies of sea-ice biota will complement this observation program to address the role of cryo-pelagic coupling in the ecosystem of Fram Strait. Overall, the objectives of this expedition are directly related to the implementation of the research program "Changing Earth - Sustaining our Future" of the research field "Earth and Environment" of the Helmholtz Association, in which the AWI is involved together with six other Helmholtz Centres. Here, the expedition contributes directly to the implementation of the research goals of Topic 2 "Ocean and cryosphere in climate" and Topic 6 "Marine and Polar Life: Sustaining Biodiversity, Biotic Interactions and Biogeochemical Functions". In Topic 6 (Subtopics 6.1 "Future ecosystem functionality" and 6.3 "The future biological carbon pump"), the ecosystem shifts in the pelagic and deep ocean associated with rising water temperatures and the retreat of sea ice are determined and quantified, and feedback processes on oceanographic processes are investigated. The investigations include the characterization of spatial and temporal developments in the function of selected plankton and benthic communities, as well as the establishment of a comprehensive repository for observational data.

As part of the expedition, multidisciplinary investigations will be carried out covering almost all compartments of the marine ecosystem at a subset of stations. Selected stations of LTER HAUSGARTEN will be revisited after their investigation on PS143/1 on PS143/2 to study short-term developments of the system. In the water column, studies on biodiversity, biomass and distribution of different plankton groups and the associated biogeochemical parameters will be carried out. Classical microscopy and biogeochemical analysis are used in parallel with the latest optical and molecular genetic high-throughput methods. Complementary to the investigations in the water column, investigations of biodiversity, biomass and distribution of benthic organisms of different size classes are carried out. Measurements of oceanographic and chemical parameters supplement biological and biogeochemical parameters in the pelagic and in the benthos of the Fram Strait. Together with studies on the mechanisms and extent of vertical export of organic matter in the water column, the findings and data from the long-term pelagic and benthic observations will contribute to a better understanding of the carbon flux in the Arctic Ocean. The implementation of the scientific objectives of this expedition includes the use of various optical observation systems and targeted samplers for pelagic and benthic studies, as well as the collection and deployment of moorings equipped with sediment traps, sensor systems or automatic samplers. In addition, the use of an autonomous underwater vehicle (AUV) and gliders is planned. After leaving Tromsö, samples will be taken continuously

from the lower atmosphere in parallel to the previously described work program in order to determine the concentrations of ammonia and ammonium in the atmosphere, as part of the italien project GIAIA.

Overall, station work will begin in the eastern part of LTER HAUSGARTEN and then continue in western Fram Strait, and finally end in the northern part of the long-term observatory. After completion of station work, the expedition will end after a short transit of ~ 2-3 days on 06.08.2024 with the arrival in Tromsö.

2. DEEP SEA ECOLOGY AND TECHNOLOGY

Normen Lochthofen[1], Lilly Boehringer[1], Christian Detsch[1], Michael Busack[1], Babett Günther[2], Nils Handelmann[1], Jonas Hagemann[1], Sascha Lehmenhecker[1], Janine Ludszuweit[1], Autun Purser[1], Vincent Schnell[3];

not on board: Christina Bienhold[1], Ulrich Hoge[1], Christoph Krämmer[1], Ingo Schewe[1], Thomas Soltwedel[1], Matthias Wietz[1]

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Grant-No. AWI_PS143/2_01

Objectives

The marine Arctic has played an essential role in the history of our planet over the past 130 million years and contributes considerably to the present functioning of the Earth and its life. The last 25 years of the HAUSGARTEN project covered a period, which has seen remarkable changes in key Arctic variables, including a decrease in sea-ice extent and sea-ice thickness, changes in temperature and salinity of Arctic waters, and associated shifts in nutrient distributions. Since Arctic organisms are highly adapted to extreme environmental conditions with strong seasonal forcing, the accelerating rate of recent climate change challenges the resilience of Arctic life. The stability of a number of Arctic populations and ecosystems is probably not strong enough to withstand the sum of these factors, which might lead to a collapse of subsystems.

Benthos, particularly in deep waters, is a robust ecological indicator for environmental changes, as it is relatively stationary and long-lived and reflects changes in environmental conditions in the oceans (e.g. organic flux to the seabed) at integrated scales (Gage and Tyler 1991; Piepenburg 2005). To detect and track the impact of large-scale environmental changes, and to determine experimentally the factors controlling deep-sea biodiversity, the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) established the deep-sea observatory HAUSGARTEN, which constitutes the first and longest running open-ocean long-term observatory in a polar region (Soltwedel et al. 2016) – 25 years in 2024.

HAUSGARTEN is located in the eastern Fram Strait, in the transition zone between the northern North Atlantic and the central Arctic Ocean, and includes 21 permanent sampling sites along a depth transect (250 – 5,500 m) and along a latitudinal transect following the 2,500 m isobath crossing the central HAUSGARTEN station. Multidisciplinary research activities at HAUSGARTEN cover almost all compartments of the marine ecosystem from the pelagic zone to the benthic realm, with some focus on benthic processes. Regular sampling as well as the deployment of moorings and different stationary and mobile free-falling systems (Bottom-Lander, Benthic Crawler), which act as local observation platforms, have taken place since the observatory was established in 1999. Frequent visual observations with towed photo/video systems allow the assessment of large-scale epifauna distribution patterns as well as their temporal development.

Geographical features in the HAUSGARTEN area provide a variety of contrasting marine landscapes and landscape elements (e.g. banks, troughs [marine valleys], ridges and moraines, canyons, and pockmarks) that generally shape benthic communities over a variety

of different scales (Buhl-Mortensen et al. 2010, 2012). The habitat-diversity (heterogeneity) hypothesis states that an increase in habitat heterogeneity leads to an increase in species diversity, abundance and biomass of all fauna groups (Whittaker et al. 2001; Tews et al. 2004). Improved technologies, particularly the recent deployment of acoustic and side-scan sonar systems at depth by AUV and towed camera sleds within the AWI Deep-Sea Research Group (Purser et al. 2019) has indicated the high-resolution topographical variability of many deep-sea areas, including HAUSGARTEN (Schulz et al. 2010; Taylor et al. 2016; Purser 2020). So far, the time-series stations maintained across the region do not capture the high degree of local heterogeneity (in terms of physical seafloor terrain variables such as slope, rugosity, aspect, depth). Therefore, during *Polarstern* expedition PS143/2, additional spatial investigations to capture the role of this heterogeneity in biodiversity and biomass estimation are planned to complement investigations on the temporal variability of benthos in the HAUSGARTEN area.

Benthic communities are strictly dependent on carbon supply through the water column, which is determined by temporal and spatial variations in the vertical export flux from the euphotic zone but also lateral supply from shelf areas. Most organic carbon is recycled in the pelagic, but a significant fraction of the organic material ultimately reaches the seafloor, where it is either re-mineralized or retained in the sediment record. One of the central questions of the biogeochemical studies at HAUSGARTEN is to what extent sea-ice cover controls primary production and subsequent export of carbon to the seafloor on a seasonal and interannual scale. Benthic oxygen fluxes provide the best and integrated measurement of the metabolic activity of surface sediments. They quantify benthic carbon mineralization rates and thus can be used to evaluate the efficiency of the biological pump. In order to link long-term variations in surface and sea-ice productivity and consequently in export flux to the seafloor, detailed investigation of the temporal variations in benthic oxygen consumption rates would be very valuable. Yearly measurements with free-falling devices (bottom-lander) provide information on the interannual variations. Benthic crawlers, mobile seafloor platforms capable to perform weekly oxygen gradient measurements for a 12-month period, provide information on the seasonal variations.

Work at sea

The current cruise will continue this time series work into its 25th year, and will serve to detect long-term changes of benthic communities. The composition, diversity, density and biomass of benthic communities will be analysed together with environmental data to detect changes due to environmental regime shifts in the deep sea of the Fram Strait. Within a complementary sampling design covering all size classes of benthic communities from meio- to megafauna.

Long-term meiobenthic study

Virtually undisturbed sediment samples are taken using a video-guided multiple corer (MUC, Fig. 2.1). Various biogenic compounds from these sediments are analysed to estimate activities (e.g. bacterial exoenzymatic activity) and the total biomass of the smallest sediment-inhabiting organisms. Results will help to describe ecosystem changes in the benthal of the Arctic Ocean. Sediments retrieved by the MUC will also be analysed for the quantitative and qualitative assessment of the small benthic biota.

Meiofauna spatial and temporal distribution patterns, with special focus on density and diversity of nematode community composition will be analysed.

Sediments are sampled to describe small-scale spatial patterns as vertical gradients within the sediment as well as large-scale patterns for different water depths. The first 25 years of the HAUSGARTEN time series have been or are being evaluated as part of doctoral dissertations focusing on nematode community patterns. In order to continue this unique time series in the future, sediment cores are taken along the HAUSGARTEN depth transect for the analysis of

the meiofaunal communities. These cores will also be sub-sampled for various environmental parameters indicative of the food input to the deep seafloor.

In addition, these samples will serve as background information for various biological experiments investigating the causes and effects of gradients on biodiversity patterns and community composition of benthic organisms to be installed at the central HAUSGARTEN station during future expeditions.

During PS143/2 MUC sampling will be opportunistic and not a key focus of the onboard work, with the majority of sampling for 2024 being taken during PS143/1. Despite this samples may be collected. In an addition to the sampling described above, sediments will also be collected as part of Project HaploSEA, which is funded via Marie Skłodowska-Curie Actions (MSCA) as an MSCA Postdoctoral Fellowship at GEOMAR (Grant agreement ID: 101108076, https://doi.org/10.3030/101108076). The Project is evaluating the use of meta-genetic diversity for biological assessments of deep-sea benthic communities. Sediment samples will be collected via the Multicores, with at least three cores per station where possible. Processing and later analyses are based on the standardised protocols aiming to analyse whole biodiversity across the tree of life via metabarcoding and novel capture by hybridisation approach. (Brandt et al. 2020 & 2021). The data will be included in the eDNAabyss-dataset, allowing the comparison of over 1500 samples worldwide.

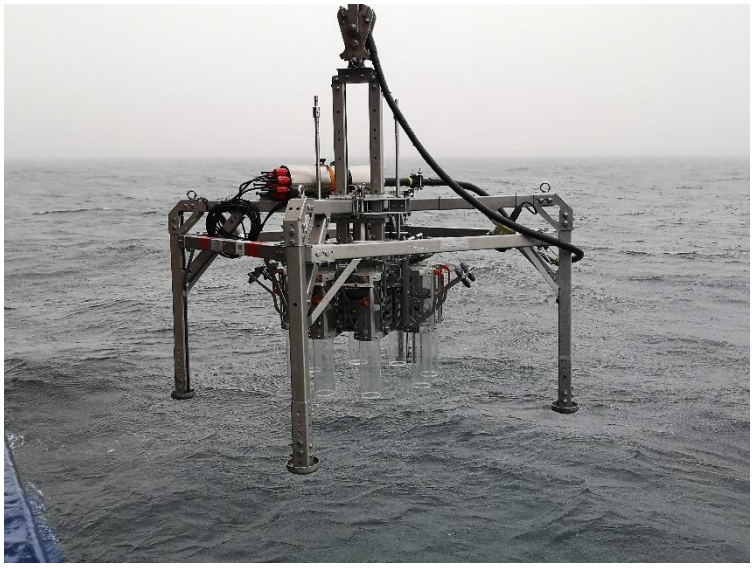

Fig. 2.1: Multicorer used for sampling infauna and for meta-genetic diversity during PS143/2. PHOTO: Jannik Schnier

Long-term megabenthic study and seafloor mapping

The newly constructed Ocean Floor Observation and Bathymetry System II (OFOBS; Purser et al. 2019) was field tested during the PS138 expedition in 2023. During PS143/1 and PS143/2 in 2024 the system will be deployed along previously established and analyzed camera tracks to assess interannual dynamics of megafauna on the seafloor at selected stations (ideally HG-I, HG-IV, N3, S3, but with potential changes made in response to ice and weather conditions). The OFOBS will be towed at 1.5 m altitude for 4-hours at each survey site. A subset of images will be analyzed and compared with previous data to assess interannual dynamics of megafaunal assemblages. The AWI “Remora class” MiniROV will be attached to OFOBS for some deployments and used to close up imaging work, or equipment retrieval, as required (Fig. 2.2).

Fig. 2.2: OFOBS Camera sled, with miniROV mounted on the rear. This system will be used to both image and map regions of seafloor. PHOTO: Jannik Schnier

The imagery will also be used to quantify litter on the seafloor. The OFOBS II is equipped with a multibeam system allowing to collect spatial data to develop the high-resolution seafloor topographical maps of the HAUSGARTEN. During PS143/2 a newly developed sampling net device will be mounted on OFOBS II behind the stil camera. The aim of this net is to allow the directed sampling of fauna on the seafloor, such as small sponges or holothurians. This device will be trialled during the expedition in expectation of extended use during the PS146 Antarctic expedition in Dec 2024.

In addition to the OFOBS system, the AWI AUV ‘PAUL 3000’ (Fig. 2.3) will be used during the PS143/2 expedition to continue the spatial mapping of HAUSGARTEN stations, and to further explore the seafloor surrounding the time series stations. During PS143/2 the intention is to operate the AUV autonomously without direct attendance by the research vessel. This will allow the expedition to carry out additional work whilst AUV seafloor surveys are conducted with the AUV mounted sidescan and camera systems. A key aim is to start in 2024 the linking of the various HAUSGARTEN stations with seafloor image transects, to identify spatial patterns in community structure across the survey region. Depending on weather conditions, the initial plan is to commence this work with the stations adjactent to Svalbard. The AUV and OFOBS will also be available to image seafloor areas of opportunity below the planned Triaxus transects to be conducted by other onboard working groups.

All data collected with the OFOBS II and the AUV will be used to test a new data archiving ingest protocol developed by C. Krämmer and L. Boehringer, strictly following the guidelines and metadata schemes presented in Schoening et al. (2022).

Fig. 2.3: The AUV 'PAUL 3000' , used for both imaging and acoustically mapping the sea floor to depths of 3000 m during PS143/2. PHOTO: Klara Köhler

Measurements of the vertical flux of particulate matter at HAUSGARTEN have been conducted since the establishment of the observatory. By means of these measurements we are able to quantify the export of organic matter from the sea surface to the deep sea, and trace changes in these fluxes over time. The organic material which is produced in the upper water layers or introduced laterally from land is the main food source for deep-sea organisms. Measurements of organic matter fluxes are conducted by bottom-tethered moorings (Fig. 2.4) carrying sediment traps at approx. 200 and 1,000 m below sea-surface, and about 200 m above the seafloor. In addition to moored sediment traps, autonomous infrastructure will be deployed on the HAUSGARTEN moorings to track seasonal changes in the dissolved and particulate constituents of the upper water column. These include remote access water samplers (RAS) that are programmed to collect and preserve water samples (~0.5 L). Besides sediment traps and RAS, the moorings are equipped with current meters, self-recording CTD's, and a suite of biogeochemical sensors. During *Polarstern* expedition PS143/2, we will recover and redeploy moorings and instruments that were deployed during 2023.

At all stations where moorings are deployed, we will conduct CTD/Rosette Water Sampler casts from the surface close to the seafloor. Water samples will be taken for the analyses of chlorophyll a, particulate organic carbon and nitrogen (POC/N), particulate phosphorous, biogenic particulate silica (bPSi), total particulate matter (seston), calcium carbonate (CaCO3), and the stable isotopes content (δ15N/δ13C) in the particulate matter. This work as well as the sampling and sensing at the other HAUSGARTEN stations will be conducted in close cooperation with the PEBCAO Group (Plankton Ecology and Biogeochemistry in a Changing Arctic Ocean) at AWI. Additionally, CTD waters will be subsampled for eDNA analysis. The aim is to collect water for metazoan detection via eDNA metabarcoding. Samples will be collected with the water bottle rosette every 100 m and in specific stages. Two litres of water will be filtered in triplicate. This is a follow-up repletion of sampling in the years 2022 and 2023, partly already published (Merten et al. 2023). While general Metazoan diversity is of interest, a particular focus lies on fish and cephalopod detections and comparison of species richness over the years. Extra water will be filtered for a pilot study, including the new Capture by Hybridization for complete reconstruction of genes of target groups. Stations with parallel sampled benthic sediment will be compared regarding further analyses of benthic-pelagic coupling.

Fig. 2.4: Autonomous winch developed by technicians within the Deep Sea Ecology and Technology group in AWI, being deployed at HAUSGARTEN. These moorings winch throughout the year at programmed times to collect environmental information from the waters just below the sea ice, from regions where fixed moorings may be at risk. PHOTO: Mario Hoppmann

Pelagic studies

At all stations where moorings are deployed, we will conduct CTD/Rosette Water Sampler casts from the surface close to the seafloor. Here, water samples will be taken for the analyses of chlorophyll a, particulate organic carbon and nitrogen (POC/N), particulate phosphorous, biogenic particulate silica (bPSi), total particulate matter (seston), calcium carbonate (CaCO3), and the stable isotopes content (δ15N/δ13C) in the particulate matter. This work as well as the sampling and sensing at the other HAUSGARTEN stations will be conducted in close cooperation with the PEBCAO Group (Plankton Ecology and Biogeochemistry in a Changing Arctic Ocean) at AWI. Additionally, CTD waters will be subsampled for eDNA analysis of prokaryotic and metazoan biodiversity. Samples will be collected with the water bottle rosette every 100 m and in specific stages. Two litres of water will be filtered in triplicate. This is a follow-up repletion of sampling in the years 2022 and 2023, partly already published (Merten et al. 2023). While general Metazoan diversity is of interest, a particular focus lies on fish and cephalopod detections and comparison of species richness over the years. Extra water will be filtered for a pilot study, including the new Capture by Hybridization for complete reconstruction of genes of target groups. Stations with parallel sampled benthic sediment will be compared regarding further analyses of benthic-pelagic coupling.

Preliminary (expected) results

There are several expected outcomes from the work to be conducted by the HAUSGARTEN group on the PS143/2 expedition. We expect to add another year of environmental water column data to the 25 yr archive from a number of the regularly visited stations, and to also record seafloor images from these stations to facilitate the continued assessment of changing benthic seafloor community structure over time.

In addition to the continuation of the time series measurements we expect with the AUV to start phototransects between HAUSGARTEN stations which will eventually greatly add to our understanding of how spatial patterns in faunal seafloor communities change with depth, distance from shore, ice coverage etc. The AUV and OFOBS deployments will also continue to build on our growing collection of high-resolution seafloor topography data which has been collected during the last 5 years with acoustic mapping systems mounted on these subsea

platforms. We also expect to get some early results on the applicability of using meta-genetic diversity for biological assessments of deep-sea benthic communities.

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the 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). All OFOBS and AUV collected image, video and sensor data will be uploaded to the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within six months of expedition completion, and made pubically available within two years after the end of the expedition at the latest. eDNA sediment and watercolumn datasets will be stored and analysed at the GEOMAR Institute and the University of Kiel facilities. They will be published in genetic repositories (European Nucleotide Archive, ENA) and linked databases such as PANGAEA and BioSamples. Further, all references, developed protocols, and analysing scripts will be made public via GitHub. Everything will be analysed and published under FAIR principles.

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

In all publications based on this expedition, the **Grant No. AWI_ PS143/2_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.

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3. PELAGIC BIOGEOCHEMISTRY

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Objectives

We will continue with our time series observations of biogeochemical variables via the collection of seawater samples and deployment of bioeochemical packages. These biogeochemical packages consist of remote access samplers (RAS) equipped with several sensors (SUNA nitrate, pH, pCO2, CTD-O2, PAR and Eco-triplet) and we have been deploying them in Fram Strait as part of the FRAM/HAUSGARTEN long-term observation activities since 2018. Whenever possible, we have deployed 4 of these biogeochemical packages in two moorings (EGC, F4S and/or F4W-1), targeting sub-surface and core waters of the East Greenland Current and West Spitsbergen Current. Deployments (and eventual recoveries) in this configuration have then taken place during PS121 in 2019 and PS126 in 2021. In 2022, during PS131, only two biogeochemical packages were deployed in subsurface waters as the other two RAS were deployed elsewhere as part of the ATWAICE expedition. In 2023 during PS136, again only 2 biogeochemical packages were deployed in Fram Strait, as 2 other sets were later deployed in the central Arctic Ocean during PS138. With the RAS we collect - typically- 48 seawater samples at roughly weekly intervals, for later analysis of dissolved inorganic and organic nutrients. Additionally, we also collect water samples from CTD-Rosette casts for nutrient analysis onboard. The rationale of our work has already been decribed in previous booklets and cruise reports (e.g., von Appen 2018; Metfies 2019, 2020; Soltwedel 2021a,b; Kanzow 2022). Briefly, our aim is to use data from sensors and RAS deployments, in combination with data from CTD casts to assess temporal variability of biogeochemical variables associated with inflowing and outflowing water masses in Fram Strait. This will allow us to evaluate the role of water property exchange in the deepest gateway of the Arctic, within the context of Arctic Ocean nutrient budgets. As in previous expeditions, we carry out these deployments in collaboration colleagues within the FRAM community; the Microbial Observatory (PIs Katja Metfies, Christina Bienhold, and Matthias Wietz), Physical Oceanography of Polar Oceans (PIs Wilken von-Appen, Mario Hoppmann, Matthias Monsees, Torsten Kanzow) and Deep-Sea Ecology and Technology (Normen Lochtofen). During PS136 we also started a new collaboration with colleagues (Adrian Martin and Peter Brown) from the National Oceanography Centre, Southampton (UK) as part of their BIOPOLE programme (https://biopole.ac.uk/). They provided an extra RAS that was deployed at approx. 200 m in the EGC mooring to complement our work.

Work at sea

(1) We will collect water samples from selected repeated CTD-Rosette casts/stations for later analysis of dissolved nutrients.

(2) We also plan to collect seawater samples associated with Triaxus sections, for later analysis of nutrients.

(3) We will deploy 4 biogeochemical packages; i.e., FRAM RAS and sensors.

(4) We will recover the bioeochemical packages deployes in 2023 during PS136, including the RAS provided by our colleagues from the UK. This RAS will be subsampled onboard and the remaining samples will be picked u together with RAS and tools, by our colleagues, at the end of the *Polarstern* Arctic season.

Preliminary (expected) results

Upon mooring recovery, data retrieval, processing and quality control of sensor data will take up to 6 months. Analysis of nutrients from RAS samples may also take 6 months or more after the expeditions. We aim to process the data from measurements carried out on board, which will only require further quality control after the expedition.

Data management

All nutrient data and sensor 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.

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

In all publications based on this expedition, the **Grant No. AWI_ PS143/2_02** will be quoted and the following publication will be cited:

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

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4. PHYSICAL OCEANOGRAPHY

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Grant-No. AWI_PS143/2_03

Objectives

The physical conditions that lead to enhanced primary and export production in the Arctic Ocean remain unclear. With both, rapid increases in ocean temperatures amplified in the Arctic region and sea ice retreat of the past two decades, the connection between these physical changes and the effect on polar marine ecosystem only increases in importance.

The intermittent presence of sea ice and meltwater affects both the physical and biochemical vertical structure of the water column but also limits *in situ* observations to summer months when the ice has retreated. The effects of changes in the environmental conditions on the polar marine biodiversity can only be detected through long-term observation of the species and processes. The FRAM multidisciplinary observatory attempts to observe the coupling across the system atmosphere, upper ocean, pelagic, and benthic environments.

The monitoring program of the Atlantic Water (AW) inflow into the Arctic via the West Spitsbergen Current (WSC) started in 1997. PS143/2 will contribute to maintaining this long-standing time series observatory, as the AW inflow conditions drive the changing physical (and also biogeochemical and biological) properties of the Arctic Ocean.

The Frontiers in Arctic Marine Monitoring (FRAM) Helmholtz infrastructure initiative has increased the ability to observe the temporal evolution of the coupled physical-chemical-biological system in the upper water column and troughout the water column to the sea floor. Continuing these interdisciplinary time series will allow for the evaluation of interannual variations in addition to shorter term interactions on submesoscale to seasonal timescales. Two main multidisciplinary time series locations are pursued in the framework of FRAM and its continuation: F4 site at 1000m water depth in the inflowing Atlantic Water boundary current (West Spitsbergen Current) and EG4 site at 1000m water depth in the outflowing Polar Water boundary current (East Greenland Current). By clearly being embedded in very different water masses representing end points of Arctic conditions, they will allow for a better prediction of what is to be expected in the Arctic Ocean. Submesoscale dynamics take place on horizontal scales of <1km to a few km in Fram Strait. They are a key process that achieves the subduction of Atlantic Water below Polar Water as the Atlantic Water recirulates in Fram Strait. However, the temporal statistics of the submesocale are still unknown.

Ocean-sea ice coupling in the marginal ice zone (MIZ) is related to key mechanisms of rapid Arctic sea ice decline and Arctic Amplification. These include processes affecting heat fluxes in the air-ice-ocean system, ocean mixed layer-halocline coupling, ice melt and ice edge dynamics in the MIZ. We posit that oceanic eddies, fronts and tidal mixing shape the sea ice distribution in the MIZ which leads to locally enhanced ice melting as well as to the generation of stratified areas with suppressed melting. These processes result in sea ice characteristics that can be distinguished by different gradients of sea ice floe size, concentration, roughness

and thickness. Our study also aims to understand the complex physical-chemical-biological interactions that control biogeochemical cycling and ecosystem functioning.

Work at sea

CTD/Rosette Water Sampler

The CTD rosette will be deployed at all mooring sites and at the standard HAUSGARTEN stations. The CTD will be equipped with dual temperature, conductivity, and oxygen sensors as well as single chlorophyll fluorescence, transmissivity, CDOM, and PAR sensors. We will also attach SBE37 microcats and SBE56 temperature loggers to the rosette for a few casts to perform *in-situ* sensor calibration casts. Water samples from the CTD rosette will be run on the salinometer and oxygen titration rig to support the calibration/data processing of the conductivity and oxygen sensors, respectively. Water samples will be collected both on full water column profiles and on profiles to only 300 m depth.

Mooring recoveries and deployments

As listed in Table 4.1, we will recover 11 oceanographic moorings and deploy 9 moorings. These moorings generally contain observations for water temperature and salinity as well as current velocity. Additionally, some also target sea ice properties and biogeochemical/ biological parameters. The upper ocean physical-biological cluster at F4 will have an instrument setup similar to what has been used at HG-IV and F4 in eastern Fram Strait since 2016 (e.g. PS99.2/PS107/PS114/PS121/PS126/PS131/PS136). A mooring will also include a winch to measure profiles in the top 100m of the water column. At F4 we will also deploy a new mooring (F4-H-1) which together with moorings F4-22 and F4-S-8 will form an equilateral triangle with 1400m side length. Horizontal velocity and temperature/salinity will be measured at all three moorings between 50m and 250m depth. This will allow the calculation of horizontal velocity and buoyancy gradients at the submesoscale. It will provide the first year-round measurements of these submesoscale quantities in a high latitude boundary current.

Tab. 4.1: List of planned mooring operations.

Name	Longitude		Latitude		Depth	Top	Deployment time UTC					Deployment station
	Degrees	Minutes	Degrees	Minutes	Meters	Meters	Year	Month	Day	Hour	Minute	
Recoveries												
F2-21	8	19.91 E	79	0.01 N	786	20	2022	7	8	15	52	PS131_25-1
F3-20	7	59.93 E	78	59.98 N	1074	38	2022	7	8	13	42	PS131_24-1
F4-21	7	0.03 E	79	0.02 N	1224	50	2022	7	7	8	54	PS131_15-1
F4-S-7	6	57.75 E	79	00.67 N	1253	20	2023	6	6	21	22	PS136_020_01
F4-OZA-3	6	19.91 E	79	10.00 N	1416	89	2022	7	8	9	33	PS131_23-1
F5-20	5	39.97 E	79	0.02 N	2091	34	2022	7	7	16	25	PS131_17-1
HG-IV-FEVI-46	4	19.77 E	78	59.95 N	2599	39	2023	6	1	9	20	PS136_008_02
HG-EGC-8	5	23.74 W	78	59.78 N	1011	47	2022	8	3	17	37	PS131_106-1
HG-EGC-9	5	25.09 W	78	59.34 N	979	48	2023	6	13	16	4	PS136_033_07
Y2-1	10	3.65 E	80	25.00 N	693	128	2022	7	18	9	53	PS131_59-1
Y8-1	3	10.27 E	81	18.82 N	800	16	2022	7	29	5	34	PS131_85-1
Deployments												
F2-22	8	19.91 E	79	0.01 N	786	20	2024					
F3-21	7	59.93 E	78	59.98 N	1074	38	2024					
F4-22	7	0.00 E	79	0.00 N	1224	50	2024					
F4-S-8	7	2.00 E	79	0.70 N	1231	16	2024					
F4-W-5	6	58.00 E	79	0.70 N	1249	132	2024					
F4-H-1	7	4.00 E	79	0.00 N	1210	50	2024					
F5-21	5	39.97 E	79	0.02 N	2091	34	2024					
HG-IV-FEVI-48	4	19.94 E	78	59.99 N	2568	38	2024					
HG-EGC-10	5	23.74 W	78	59.78 N	1011	47	2024					

Underway temperature/salinity/velocity

Throughout the cruise we will operate the underway thermosalinograph to get surface ocean hydrographic properties and we will operate the 150kHz RDI OceanSurveyor vessel mounted ADCP.

Triaxus

We will tow the Triaxus towed ocean profiler of the AWI (topAWI) along a number of east-west sections from medium concentration pack ice into the open ocean, e.g. along 79°N and 81°N. For this a depressor system will be employed whose purpose is to pull the towing cable straight down behind the ship's stern such that the towing cable will not become entangled in sea ice. The sections will be 100-200km long and cover the top 300m of the water column at high (sub-kilometer) spatial resolution. Sensor based physical, biogeochemical, biological, and optical measurements will be undertaken, among others with a SBE911+ system mounted to the Triaxus. In case the Triaxus should not be operational or the sea ice conditions should prohibit its operation, similar sections will be occupied with the Teledyne Oceanscience underway CTD (UCTD) system.

Sea ice measuring system (SIMS)

In order to better resolve the ice thickness variability and gradients and their temporal change across the MIZ, we will use an EM sounder deployed from the bow of the ship (Sea Ice Monitoring System SIMS) to measure ice thickness continuously along the ship's track, in conjunction with the Triaxus towed system. This requires that during the numerous transects

across the MIZ the ship travels along straight, representative tracks without avoiding ice by circumnavigating it.

Data management

All sensor 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.

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

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5. PEBCAO – PLANKTON ECOLOGY AND BIOGEOCHEMISTRY IN THE CHANGING ARCTIC OCEAN

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Grant-No. AWI_PS143_04

Outline

The Arctic Ocean has gained increasing attention in recent decades due to the ongoing significant changes in sea-ice cover and increase in sea temperature. Moreover, it is expected that the chemical equilibrium and the elemental cycling in the surface ocean change due to ocean acidification. The PEBCAO group began its studies of plankton ecology in Fram Strait (~79°N) in 1991 and intensified its efforts in 2009. Since then, measurements of biogeochemical parameters, microscopy, optical methods, satellite observations, and molecular genetic approaches have been combined in a holistic approach to collect comprehensive information on the variability in biodiversity, biogeography and biomass of the bacterial, microbial and mesozooplankton plankton communities as well as of primary production and bacterial activity on an annular basis. As part of the PEBCAO contribution to the HAUSGARTEN/FRAM observatory, this also included the deployment of sediment traps and automated water samples on long-term moorings.

The long-term observations and process studies of the past years have already given us valuable insights into mechanistic linkages between environmental conditions, biodiversity and ecosystem functionality, and into ongoing change in the marine ecosystem of Fram Strait. Our results clearly indicate that chlorophyll a (Chl-a) values increase in summer in the eastern but not in the western Fram Strait (Nöthig et al. 2015, 2020). This is in accordance with the increasing contributions of *Phaeocystis pouchetii* and nanoflagellates to the summer phytoplankton community in relation to diatoms, linked to decreasing availability of silicic acid in the water column. Silicic acid in the Eurasian Basin of the Arctic mainly originates from the North Atlantic Water (NAW) inflow (100-400 m water depth) through Fram Strait and the Barents Sea Opening, and from riverine input through the Laptev Sea. Recent analyses have shown that all these waters are affected by decreasing trends in silicic acid concentrations over the last 25 years (Hátún et al. 2017). This decrease is primarily attributed to reduced winter convection depths since the mid 1990s and an increased influence of nutrient-poor water of mid-latitudes origin (Hátún et al. 2017). Although nitrate limits the total annual net primary production, spring diatom productivity, which is a major part of the total productivity, is strongly controlled by silicic acid supply (Krause et al. 2018). Fram Strait is an ideal location to study this ongoing decline in silicic acid concentrations and investigate potential effects of sea-ice coverage on phytoplankton community composition. Biogeographical studies of PEBCAO based on 18S metabarcoding indicate that a year-round semi-stationary sea-ice edge serves as a strong biogeographical boundary between Atlantic conditions to the southeast and polar

conditions to the Northwest of Fram Strait (Metfies et al. 2016). In 2017, the MIZ extended further eastwards and southwards into Fram Strait than in average years, with profound impacts on the ecosystems. Sea ice melt in a sub-mesoscale filament, characterized by a thin surface meltwater layer, led to comprehensive changes in plankton-biodiversity, carbon export and primary production in vicinity of the filament (Fadeev et al. 2021). Here, a combination of the latest biological and physical underway-measurements has proven very useful to map the physical environment, the phytoplankton overall and group specific chlorophyll-a concentration, and more specifically eukaryotic microbial community composition in a sub-mesoscale filament with high spatial resolution. Our results suggest that sea-ice melt is enhancing the growth of sea-ice associated phytoplankton, that might be positively linked to zooplankton abundance and biomass (Weiss et al. 2024). In sea-ice impacted regions of Fram Strait diatoms dominate the diet of zooplankton, while they have less impact in open water areas of Atlantic Water (Kaiser et al. 2024, submitted).

Moreover, the population size of bloom-forming species can also be impacted by mycoplankton (defined here as saprotrophic and parasitic fungi and pseudofungi (oomycetes). These taxonomic groups have not yet been part of our investigations although its ecological impact can be considerable (Buaya et al. 2019). Even in well-studied areas such as the North Sea new species are being described (Buaya et al. 2017), but in polar regions, with few exceptions the diversity and dynamics of the mycoplankton remain to be discovered (Hassett et al. 2019 a,b). Another, yet understudied group impacting marine microbial communities are bacteriophages, or phages, which are viruses that infect and replicate within bacterial hosts and play an essential role in regulating microbial populations and ecosystem dynamics (Suttle, 2007). The virome of extreme environments such as Polar Regions has only rarely been investigated due to challenges such as limited access to the ecosystem and low biomasses (Heinrichs et al. 2024). Understanding the diversity, structure, and functions of polar phages is, however, critical to advancing our knowledge of the microbial ecology and biogeochemical processes in these environments. During PS 143/2, we will therefore investigate the influence of mobile genetic elements such as phages and viruses on gene transfer and diversification within microbial communities of Fram Strait for the first time. By analyzing the genetic composition of these elements, we aim to understand their impact on the dynamics and adaptation of their host organisms.

In the past, PEBCAO also contributed to year-round interdisciplinary observations indicating that increased meltwater-stratification during spring/summer of 2017 slowed down the biological carbon pump in AW the central Fram Strait with significant impacts on pelagic and benthic communities in comparison to the warmer year 2018 (von Appen et al. 2021). The data suggest, that sea-ice melt might serve as a barrier for a northward movement of temperate phytoplankton taxa in Fram Strait (Oldenburg et al. 2024). Furthermore, based on our year-round automated water sampling, we characterized the annual succession of microbial communities at a station in West Spitsbergen Current (WSC) and East Greenland Current (EGC). The ice-free West Spitsbergen Current displayed a marked separation into a productive summer (dominated by diatoms and carbohydrate-degrading bacteria) and regenerative winter state (dominated by heterotrophic Syndiniales, radiolarians, chemoautotrophic bacteria, and archaea). In the East Greenland Current, deeper sampling depth, ice cover and polar water masses concurred with weaker seasonality and a stronger heterotrophic signature. Low ice cover and advection of Atlantic Water coincided with diminished abundances of chemoautotrophic bacteria while other taxa such as *Phaeocystis* increased, suggesting that Atlantification alters the microbiome structure and eventually the biological carbon pump (Wietz et al. 2021). PEBCAO was able to show, that a change in microbiome structure might affect the biological carbon pump. For instance, we found, strong correlations between Phaeocystis and transparent exopolymer particle concentration (TEP), which are known to play a crucial role in the biological carbon pump (Engel et al. 2017). However, despite the observed shift in phytoplankton community composition, the concentration of dissolved organic carbon (DOC) was relatively stable over the last two decades, but we observed a slight decrease in the particulate organic carbon (POC) during the summer months (Engel et al.

2019). While these results point to inter annual changes in the Fram Strait (von Jackowski et al. 2022) additional data suggest an intra annual (seasonal) succession of prokaryotic microbes, that was related to a succession in the biopolymer pool, indicating seasonally distinct metabolic regimes. Data of our long-term sediment-trap programme suggest that over the period 2009-2016 the abundance of Micromonas polaris and Micromonas commoda-like cells is positively correlated with lower standing stocks of phosphate and nitrate in the upper water-column at the LTER observatory HAUSGARTEN, and that they are exported to the deep sea, despite of their small size (Bachy et al. 2022).

In summary, our data suggest that already now the ecosystem in Fram Strait is subject to profound changes, likely induced by changing climate conditions, which warrants further, sustained observation. Here it is of particular importance to quickly improve our understanding of the effects of variable sea-ice coverage and the marginal ice zone (MIZ), respectively sea-ice melt on the ecosystems. These effects are predicted to prevail in larger areas of the AO in the future, and Fram Strait is an ideal site to study these effects since its ecosystems are already now strongly and regularly affected by sea-ice related processes in the MIZ.

Objectives

The effects of changes on the polar plankton ecology and biogeochemical processes can only be detected through a combination of dedicated interdisciplinary process studies and long-term observations, as implemented by PEBCAO within the HAUSGARTEN/FRAM observatory for more than a decade. Overall, the overarching objectives of PEBCAO are to improve the mechanistic understanding of biogeochemical and microbiological feedback processes in the changing Arctic Ocean, to document ongoing and long-term changes in the biotic and abiotic environment and to assess the potential future consequences of these changes. In particular we aim to identify climate-induced changes in the biodiversity of pelagic ecosystems and, concomitantly, in carbon cycling and sequestering and improve our mechanistic understanding of linkages between key environmental parameters and ecosystem functionality in the Arctic Ocean. The objectives are addressed in an interdisciplinary approach. In this context, the current expedition is contributing in specific to the question of how sea ice coverage over different geographical scales affect the composition of plankton and the associated ecological processes.

Primary production is expected to increase in the changing Arctic Ocean, however, it is currently unclear if this will lead to increased export of particulate organic carbon or if organic carbon will remain at the surface, fueling heterotrophic bacteria. Heterotrophic bacteria play a vital role in global biogeochemical cycles. To improve our understanding of bacterial activity, we will determine bacterial abundance, biodiversity and bacterial production. By linking compound dynamics with rate measurements and community structure, we will gain further insights into the flow of carbon through the Arctic food web. To address the effects of global change on microbial biogeochemistry in the Arctic Ocean, we will also continue to monitor concentrations of organic carbon, nitrogen, and phosphorus, as well as specific compounds like amino acids, carbohydrates, and gel particles. To assess cell abundances, we will sample for microscopic counts and flow cytometry that allows us to determine phytoplankton (< 50 µm), bacteria, and viral abundances. Phytoplankton primary production will be determined by radioisotopes (via 3H leucine-incorporation)) and distinguished into particulate primary production (carbon remaining in the cells) and dissolved primary production (organic carbon subsequently released by cells). In addition, primary production will be assessed *in situ* using fast repetition rate fluorometry (FRF) with the FastOcean ADP profiling system.

In order to investigate the effects of global change and anthropogenic pollution on the microbial community and biogeochemistry in the Arctic Ocean, we will continue to monitor the concentrations of organic carbon and nitrogen, amino acids, lipids, carbohydrates, and gel particles, and we will assess abundances of phytoplankton, bacteria and viruses. Moreover, we will study the bacterial community on microplastic, focusing on potential pathogens and

their resistance mechanisms against antibiotics to better understand the potential risks of microplastic to human and ecosystem health.

We expect that the small algae at the base of the food web gain importance in mediating element and matter turnover as well as energy fluxes in Arctic pelagic systems. In order to detect changes, also in this smallest fraction of the plankton, traditional microscopy will be complemented by optical (see below) and molecular methods that are independent of cell-size and morphological features, and we will determine their contribution to Chl-a biomass. Changes in Eukaryotic microbial communities are tightly linked to prokaryotic community composition. The assessment of the biodiversity and biogeography of Arctic Eukaryotic microbes, including phytoplankton and their linkages to prokaryotic microbial communities, will be based on analyses of eDNA via 16S and 18S meta-barcoding, and quantitative PCR. A suite of automated sampling devices in addition to classical sampling via Niskin bottles attached to a CTD/Rosette Water Sampler will be used to collect samples for eDNA analyses. This includes the automated filtration device AUTOFIM deployed on *Polarstern* for underway filtration, automated Remote Access water Samplers (RAS) and long-term sediment traps deployed on the FRAM moorings for year-round sampling.

In addtions to this, during PS143-2 we will carry out an intensive sampling campaign to study the biodiversity of marine fungi and their linkages to the phytoplankton community, continuing the work PS 143-1 to investigate the diversity and distribution of this group, and to bring both true fungi and oomycete into culture for later analysis. Changes in phytoplankton composition are corroborated by variations in the biogeochemical flux composition (Lalande et al. 2019), as well as in large zooplankton species (caught as so-called “swimmers” in sediment trap samples), which have shown an increase of warm adapted organisms in recent years (Kraft et al. 2013; Bauerfeind et al. 2014; Busch et al. 2015).

Our investigation will also include sampling for studies of the diversity and distribution of phages and viruses at different sampling sites and depths, each representing unique environmental profiles, complementing the long-term observational program LTER HAUSGARTEN.

Underway measurements of the surface phytoplankton with two devices, the FluoroProbe and the CytoSub, will help to detect spatial changes in the community. We will use the CytoSub (a Flow Cytometer) to quantify the phytoplankton community, especially the picoplankton size class, ranging from 0.2 to 2 µm. The Flow Cytometer measures the light scatter of each cell which provides information on the internal or external complexity of the cell. The fluorescence (red, orange, yellow) indicates the type of cell. All those light signals are transformed to electrical signals and are made visible in a cytogram (Thyssen et al. 2015). We will also use the FluoroProbe (bbe Moldaenke GmbH, Germany), that is a multispectral fluorometer to (1) measure total chlorophyll fluorescence and to (2) discriminate among four spectral algal groups (brown algae, cyanobacteria, green algae, and cryptophytes) and coloured dissolved organic matter (CDOM) (Artigas et al. 2019). In Arctic oceanic waters, Phaeocystis pouchetii is blooming in July (Schoemann et al. 2005), while the biomass of diatoms is decreasing during summer after a strong spring bloom (Soltwedel and Bornemann 2023). With the CytoSub, we will aim to detect *P. pouchetii* cells in different life stages and with the with the Fluoroprobe we will discriminate haptophytes from brown algae. The dominating phytoplankton class is eukaryotic picophytoplankton, especially chlorophytes such as *Micromonas polaris* and *Micromonas commoda* (Bachy et al. 2022), and these can be detected with the CytoSub (RedPico) and, if their biomass is large, with the FluoroProbe.

Optical measurements of the phytoplankton will be acquired continuously during PS143/2. We will determine total phytoplankton and group specific Chl_a concentrations, as well as the absorption by other particles and colored dissolved organic matter. We will broaden the sampling frequency of information on phytoplankton, particulate and chromophoric dissolved organic matter (CDOM) abundance and composition by taking continuous optical measurements which directly give information on inherent and apparent optical properties (IOPs, and AOPs, respectively). We collect a high spatial and temporal resolved data set on phytoplankton (total and composition) and its degradation products at the surface and for the

full euphotic zone, using continuous optical observations during the entire cruise and at specific transects operated by towing the Triaxus platform, respectively. This large data set will be calibrated using high precision measurements on discrete water samples and combined with ocean colour satellite data to upscale the station-based information on linkages between the various trophic layers and biogeochemical cycling. Further, these data will be used for validating several ocean color satellite products (e.g., Oelker et al. 2022; Xi et al. 2021; Bracher et al. 2009).

Similarly to the phytoplankton community, the zooplankton community composition may shift due to the increasing inflow of warmer Atlantic water into the Fram Strait. Altered zooplankton trophic interactions and community compositions will have consequences for the carbon sequestration and flux. Most of our knowledge on zooplankton species composition and distribution has been derived from traditional multiple net samplers, which integrate depth intervals of up to several hundred meters. Nowadays, optical systems, such as the zooplankton recorder LOKI (Light frame On-sight Key species Investigations), continuously take pictures of the organisms during vertical casts. Linked to each picture, hydrographical parameters are being recorded, i.e. salinity, temperature, oxygen concentration, and fluorescence. This will allow us to exactly identify distribution patterns of key taxa in relation to environmental conditions. We will also use the UVP5 (Underwater Vision Profiler), which is mounted on the ship´s CTD to also tackle zooplankton distribution patterns, albeit with much less taxonomic resolution than with LOKI.

Moreover, we will also include research dedicated to protistan parasites. These are severely understudied in the marine realm although they are likely to affect the population dynamics of phytoplankton (including bloom timing and magnitude) and zooplankton. We will therefore conduct a baseline study of the diversity of different parasite groups and their association with potential hosts. This investigation will also form the basis for future biogeographic studies. The analyses will combine different microscopy techniques (LM, SEM, CFLM) as well as molecular data, the latter facilitating observation of parasitism even at times where easily discernible parasite life-cycle stages are absent. We will also initiate cultures for fungal plankton (in addition to oomycete cultures established on PS143/1). Co-cultures of parasites and their hosts will be used for experiments planned in the upcoming INDIFUN-AI BMBF project in which we wish to investigate the utility of using parasites and saprotrophic fungi as indicators of environmental change.

In summary, during PS143/2 PEBCAO is addressing the following objectives:

- Monitoring biogeochemical parameters
- Determine autotrophic and heterotrophic microbial activities
- Monitoring plankton species composition and biomass distribution
- Assessing the flux of particulate organic matter to the seafloor
- Investigating selected phyto- and zooplankton (including their parasites)
- Determining the composition of organic matter and gel particles
- Sampling mycoplankton to study diversity and dynamics (PS143-1 & PS143-2)
- Studying host-parasite systems in phyto- and mycoplankton

Work at sea

Microbial communities and biogeochemistry

In order to investigate the effects of global change and anthropogenic pollution on the microbial community and biogeochemistry in the Arctic Ocean, we will continue to monitor the concentrations of organic carbon and nitrogen as well as specific compounds such as amino acids, lipids, carbohydrates, and gel particles. Furthermore, we will continue to assess cell abundances via flow cytometry to determine the distribution of phytoplankton, bacteria and

viruses and confocal laser scanning microscopy (CLSM) and CLASI-FISH to analyse gel particle associated bacterial community structure.

Additionally, we will collect microplastic particles (> 300 µm) at selected stations from the surface water via the moon pool. Subsequently, we will analyse the biodiversity and function of plastic-associated bacteria using 16S amplicon sequencing and metatranscriptomics, focusing on potential pathogens and their resistance mechanisms against antibiotics. This will allow us to better understand the potential risks of microplastic to human and ecosystem health. All parameters except microplastic particles will be sampled from the water column using a CTD/rosette sampler at 5-6 depths in the upper 200 m. At selected stations amino acids, carbohydrates, and gel particles will be sampled at 5 additional depth between 200m and the sea floor to further investigate the export of carbon into the deep sea. Those samples will be preserved or frozen at 4°C, -20°C or -80°C and analysed in the laboratory at GEOMAR.

We will address the following parameter:

- Dissolved organic carbon (DOC)
- Total dissolved nitrogen (TDN)
- Total alkalinity (TA)
- Transparent exopolymer particles (TEP)
- Coomassie-stainable particles (CSP)
- Dissolved combined carbohydrates (dCCHO)
- Hydrolysable amino acids (dAA)
- Phytoplankton, bacterial and viral abundance
- Lipids
- RNA
- CLSM/ CLASI-FISH

Bacterial and primary production measurements will be performed at sea using ^{3}H leucine and ^{14}C bicarbonate incorporation, respectively. Phytoplankton primary production will be distinguished into particulate primary production (carbon remaining in the cells) and dissolved primary production (organic carbon exudation by cells).

Biogeochemical and biological parameters from rosette samples, including the automated filtration system for marine microbes AUTOFIM

We will collect particles for eDNA analyses of the microbial communities close to the surface (~ 10 m) with the automated filtration system for marine microbes AUTOFIM (Fig. 5.1.) and at 5-6 different depth in the photic zone using Niskin-bottles mounted on a CTD rosette. Using AUTOFIM, we will collect seawater samples at regular intervals (~ 1° longitude/latitude on the way to the study area starting as soon as possible after *Polarstern* has left Bremerhaven), while the CTD will be deployed at the permanent stations of the HAUSGARTEN observatory.

Along two transects from the open water into heavily ice-covered areas, samples for eDNA analyses will be taken in parallel to high-resolution measurements of physical and chemical parameters, as well as the composition and biomass of the phytoplankton, whose 18S DNA will already be sequenced on board. The sequence data will be used to identify areas in which vertical profiles of the transects are to be generated at selected stations. In addtition to the pelagic sampling, we will collect sea-ice samples for eDNA analyses and quantification of Chla biomass.

Fig. 5.1: The fully automated filtration module AUTOFIM is installed on RV Polarstern in the "Bugstrahlruderraum" close to the inflow of the ships-pump system. AUTOFIM is suitable for collecting samples with a maximum volume of 5 Liters. Filtration can be triggered on-demand or after fixed intervals. PHOTO: Katja Metfies

From the Niskin bottles, we will also sample for measuring the following parameters to asses biogeochemistry and biomasses:

- Chlorophyll a concentration
- Phytoplankton pigments and major groups (HPLC)
- Absorption by phytoplankton, non-algal particles and colored dissolved organic matter (CDOM)
- Particulate organic carbon and nitrogen (POC, PON)

Phytoplankton/mycoplankton analyses and cultivation work

At all stations samples from 4-5 depths (surface, 10, above chlorophyll maximum, chlorophyll maximum and below the chlorophyll maximum) wil be collected from the CTD Rosette and fixed in Formalin (for overall diversity) as well as Lugol iodine solution (for detailed assessments of fungal particles) respectively. These will be analysed post-cruise in Bremerhaven using a Planktoscope, a modular device for the high-throughput analysis of phytoplankton samples. For quality control purposes, selected samples will also be analysed using inverted and scanning electron microscopy. The Formalin fixed samples will be additionally used for CARD-FISH analysis.

In addition, net samples (20 µm mesh size) will be collected at all stations. Live samples will be analysed semi-quantitatively onboard and documented with images to produce a preliminary taxon list for the phytoplankton in general and to document possible infections of diatoms by fungi and oomycetes. An aliquot of the raw sample will be fixed in formalin for more detailed counts and taxonomic evaluation in the home laboratory after the cruise. In addition, the live samples will be used for the establishment of phytoplankton cultures. At 15 stations, 2

l of water from the CTD Rosette will be collected for molecular analyses to specifically target fungal and parasitic (especially oomycete) diversity.

In preparation for the BMBF project INDIFUN-AI (to start in September 2024), all net samples will be screened for fungal particles. Water samples from the CTD (surface waters) will be used as inoculum and also filtered and these filters will be stored in reaction tubes with 20% Glycerol for processing at the University of Bremen. Onboard isolation will be carried out using six different isolation media. The focus will be on fungi, but if during the routine screening of net samples, parasitic infections by oomycetes are discovered, these will also be taken into culture.

Underway measurements with CytoSub and FluoroProbe

To continuously measure the phytoplankton community composition, abundance, and the biomass variably at high frequency, we will connect the CytoSub and the FluoroProbe (Fig. 5.2) to the same underway sea water supply as the ferry box and other continuous measuring instruments (pCO2, photo-physiology). During stations, the FluoroProbe will be also used in a modified profiling configuration, to measure in-vivo fluorescence down to 170m. Water from different depths, collected with the CTD rosette, will be used to create discrete depth profiles with the CytoSub, by applying three protocols (one especially for Picophytoplankton, one for Nano- and Microphytoplankton and one for taking pictures of Microphytoplankton).

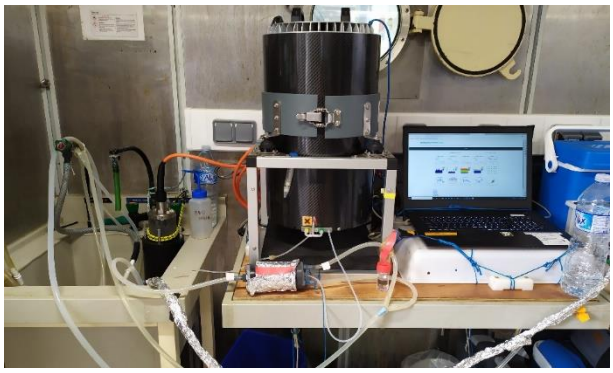

Fig. 5.2: Setup of Flow Cytometer and FluoroProbe during a cruise (credits: F. Artigas)

The CytoSub (CytoBuoy, Netherlands) is specifically designed to characterize each particle and to record the corresponding optical and pulse shape, which can be combined with imagery of selected particles, mainly in the bigger size range (Fig. 5.3). Moreover, this automated Flow Cytometer does not only focus on Pico- and Nanophytoplankton (as current benchtop FCM do) but can measure the whole size range up to Microphytoplankton single cells and colonies, for example of Phaeocystis spp. which is giving a big advantage compared to traditional flow cytometry. The CytoSub will provide an opportunity to assess microbial functional diversity continuously at and between stations and facilitate investigations of interactions and associations between different populations and their response to environmental changes.

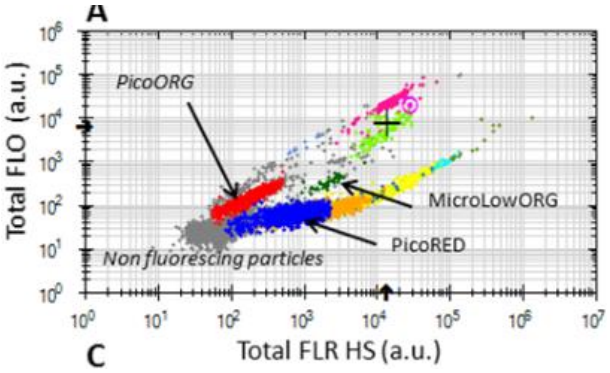

Fig. 4.3: Example of cytogram from the North Sea, highlighting chlorophyll a containing Picophytoplankton in blue (Thyssen et al. 2015)

Optical measurements

Active and passive bio-optical measurements for the survey of the underwater light field, specific light attenuation, particle and phytoplankton composition and distribution will be performed continuously on the surface water but also in the profile during Triaxus operation and daily noon-time CTD stations. For this we will operate an *in-situ*–spectrophotometer (ACS; Wetlabs) in flow-through mode to obtain total and particulate matter attenuation and absorption of surface water mounted to a seawater supply in the laboratory. A second ACS instrument to provide these properties in the water profile is mounted on a steel frame together with a depth sensor and a set of hyperspectral radiometers (Ramses sensors from TRIOS, Germany) and operated during CTD stations down to maximal 120 m. The Apparent Optical Properties of water (AOPs) (surface reflectance and light attenuation through the water column) will be estimated based on downwelling and upwelling irradiance measurements in the surface water profile (down to the 0.1% light depth) from the radiometers calibrated for the incident sunlight with measurements of a radiometer on deck. Both instruments are also mounted to the undulating platform Triaxus which also contains other biogeochemical and physical sensors (see section Physical Oceanography) and by this continuously in the water profile AOPs and IOPs will be measured hyperspectrally during the Triaxus transects. Finally, to calibrate these measurements and to validate satellite products of these properties and further derived products, such as phytoplankton groups, discrete water samples are taken as underway surface sampling (as for the ACS flow-through system at from the ship's sea water pump) at an interval of 3 hours, and at stations from the CTD rosette at six depths within the top 100 m. The water samples will be analyzed on board for: 1) CDOM absorption after filtration of the sample through 0.2 µm filters and analyzed onboard with a 2.5-m path length liquid waveguide capillary cell system (LWCC, WPI) following Levering et al. 2017 and 2) particulate and phytoplankton absorption coefficients which are determined with the quantitative filter techniques using sample filtered onto glass-fiber filters QFT-ICAM and measuring them in a portable QFT integrating cavity setup Röttgers et al. (2016). Further water samples are filtered on board immediately after sampling and the filters are thermally shocked in liquid nitrogen. Samples are stored at -80°C until ship is back in Bremerhaven and then will be analyzed for phytoplankton pigment composition within the next three months by High Performance Liquid Chromatography Technique (HPLC) at AWI following Taylor et al. (2011) adapted to our new instrumentation as described in Alvarez et al. (2022).

Sampling viruses and phages

To study the diversity and distribution of phages and viruses at different sampling sites and depths, we will sample seawater with the CTD/rosette sampler at four depths (~8 L per depth) in the upper 100 m of the water column at different sampling sites (Fig. 5.4). Using an in-line peristaltic pump system with 45 mm diameter Isopore Membrane Filters of pore sizes (3.0 µm, 0.8 µm, 0.6 µm, 0.2 µm), we will separate collected cells by size to distinguish between

plankton and prokaryote fractions for later studies. Following the 0.2 µm filtration step, the water supernatant containing viral particles passing through the filter will be incubated with $FeCl_3$ for at least 1 hour at 4°C in the dark to obtain viral iron flocculates (John et al. 2011). These are then concentrated on 0.6 µm and 0.2 µm filters. All filters containing different samples are stored at -20°C for later processing in the laboratory. To ensure comparability and integration of our results, we will synchronize our sampling with measurements of the phytoplankton, zooplankton and fungal communities.

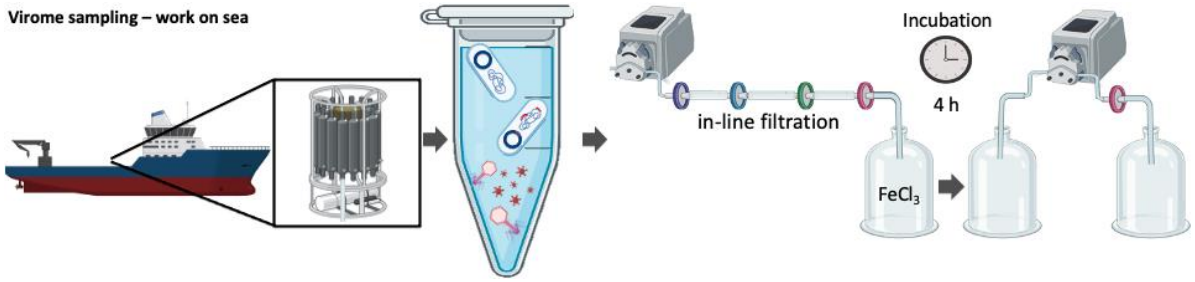

Fig. 5.4: Overview of the sampling procedure for viruses during PS143/2. Water (8 L) will be collected from the upper 100m using the CTD Rosette. Samples containing free-living and enclosed viral particles, along with putative hosts, undergo multiple filtration steps to separate the cells by size. Viral fraction enrichment is achieved through incubation with $FeCl_3$ followed by subsequent filtering.

Zooplankton sampling and optical surveys

We will study the zooplankton biodiversity and biogeography by deploying a multi net. These net samples will be immediately preserved in 4 % formalin, buffered with hexamethylene-tetramin, and later the mesozooplankton composition, biomass, size structure and depth distribution will be determined using the lab-based ZooScan system (Cornils et al. 2022). Standard multi-sampling depths are 1,500–1,000–500–200–50 m. To determine the fine scale vertical distribution of key species, we use an optical system, the zooplankton recorder LOKI (Lightframe On-sight Key species Investigations), which continuously takes pictures of organisms and particles at a frame rate of approx. 20 f sec-1 during casts from 1,000 m to the surface. At each CTD station, we will also deploy an UVP5 which also takes images of particles and zooplankton but at less optical resolution than LOKI. However, this allows to get a better spatial distribution of zooplankton abundances in the entire HAUSGARTEN area.

Flux measurements and sampling of settling aggregates

Measurements of the vertical flux of particulate matter at HAUSGARTEN have been conducted since the establishment of the observatory. By means of these measurements we are able to quantify the export of organic matter from the sea surface to the deep sea, and trace changes in these fluxes over time. Measurements of organic matter fluxes are conducted by bottom-tethered moorings carrying sediment traps at approx. 200 and 1,000 m below sea-surface, and about 200 m above the seafloor. In addition to moored sediment traps, autonomous infrastructure will be deployed on the HAUSGARTEN moorings to track seasonal changes in the dissolved and particulate constituents of the upper water column. These include remote access water samplers (RAS) that are programmed to collect and preserve water samples (~0.5 L). Besides sediment traps and RAS, the moorings are equipped with current meters, self-recording CTD's, and a suite of biogeochemical sensors. During the *Polarstern* expedition PS143/2, we will recover moorings and instruments that were deployed during the expedition PS136 in summer 2023. The BioOptical Platform (BOP) currently deployed in Fram Strait will be recovered and a new one will be deployed to measure size-specific settling velocities of individual particles in relation to their type and composition throughout a whole year. The system has been an integral part of the HAUSGARTEN mooring-array since 2015.

Expected results

Results from pelagic and sea-ice studies are expected to provide a better understanding of i) the variability and biodiversity of pelagic and sea-ice associated biomass with respect to environmental conditions, ii) trophic pathways of microbial biomass, iii) linkages between plankton community composition or biomass and biogeochemistry. The results will be published in peer reviewed scientific journals and 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. Analysis of BOP and SWIPS-Particle-Camera is quite time consuming and will therefore be done in the home laboratories at AWI and MARUM.

Data management

During our cruises, we sample a large variety of interrelated parameters. Many of the samples (i.e. Chl-a, 16S/18S eDNA, phytoplankton and zooplankton biodiversity etc.) will be analyzed at AWI or GEOMAR within approximately one year after the cruise. We plan that the full data set will be available at the latest about two years after the cruise. Samples taken for microscopical and molecular analyses, which cannot be analyzed within two years after the cruise, will be stored at the AWI for at least ten years and available upon request to other scientists. 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 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

The expedition will be supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 6, Subtopic 6.1 and Subtopic 6.3.

In all publications based on this expedition, the **Grant No. AWI_PS143_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.

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6. NEW INTEGRATED EXPERIMENTAL AND MODELLING TOOLS FOR GEOREFERENCED SOURCE APPORTIONMENT OF AEROSOL CLIMATE-RELEVANT PARAMETERS FROM MID-LATITUDES TILL THE ARCTIC ON POLARSTERN (GAIA-PS)

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Outline

Arctic warming is the result of complex global feedbacks acting at different spatial and temporal scales; our comprehension of these mechanisms is still limited and debated as related to the results obtained using modelling simulations. Among the causes of the Arctic Amplification, the role played by atmospheric aerosol is one of the most uncertain, due to difficulties in the characterization of its physical-chemical properties, their space and time variability, and uncertainties in the quantification of the contribution from its emission sources within and outside the Arctic itself. Increasing scientific interest is focused on “emerging aerosol sources” related to Arctic warming as their contribution is increasing (e.g. high-latitude dust, sea spray, biomass burning, as well as increasing contribution from anthropogenic activities in the Arctic as ship emissions or gas flaring). Some Arctic monitoring stations provide long-term series of data on ground-based aerosol properties, lidar profiles, radiometric and meteorological data. Nevertheless, it has been recently demonstrated (Losi et al. 2023; Ferrero et al. 2019a,b) that the aerosol sources identified at on-land stations can differ from those measured on a larger spatial scale, both horizontally and vertically. Thus, the possibility to use research vessels (RV) as a privileged platform for wide spatial investigations becomes crucial considering the Arctic surface covered by seawater and some RVs have already been exploited for atmospheric studies (e.g., MOSAiC (Shupe et al. 2022) and AREX (Ferrero et al. 2019a) expeditions). Apart from some simulation studies (Shindell and Faluvegi, 2009; Sand et al. 2016) no rigorous quantification of the role of aerosol sources and related aerosol-radiation climate forcing at different latitudes and over a large synergic temporal- spatial scale has been carried out via experimental activity. Receptor modelling can support this investigation. Multi-time Positive Matrix Factorization (PMF) using Multi-linear Engine (ME-2) with both chemical and optical variables (Forello et al. 2019) already proved to be a valuable tool for source apportionment (SA) of optical variables and rolling PMF (Parworth et al. 2015) has been developed and used to capture source profile temporal variabilities. Integration of these approaches has not been performed yet, but it has the potential to be a SA tool to be used on complex datasets collected at moving receptors to also provide spatial- temporal variability of source profiles. Further, a novel HR experimental quantification method (Ferrero et al. 2018; Ferrero et al. 2021a) to determine the atmospheric warming in all sky conditions (in function of cloud type and cloudiness) (Ferrero et al. 2021b) has recently been developed and has the potential to be coupled with the SA approach.

Moving in this frame, the European Union – Next Generation EU, under the Italian call PRIN, funded the GAIA project (ongoing, project 20229JLCRZ). Within GAIA, the researche units have set up a mobile lab (GAInfrA), consisting of a half-container equipped with all the instruments needed to allow a complete aerosol investigation. Further, they are implementing multi-time rolling PMF to be integrated to HR estimates: this will allow exploiting measurements obtainable using GAInfrA to reach multi-time source apportionment of HR and columnar aerosol forcing.

Targeting to high time resolution measurements is a key-aspect in this expedition to guarantee the possibility to identify temporally-limited source contribution, spatial resolution, and to provide a number of samples suitable for receptor modelling based on statistical analysis.

Objectives

GAIA-PS aims at using the mobile lab GAInfrA developed in the overarching GAIA project on the 2024 PS summer cruise, to collect geo-referenced data on aerosol chemical, physical, and optical properties, broadband and spectrally-resolved radiation budgets, and vertical structure of the atmosphere from Mid-latitudes to the Arctic. The main objective of GAIA-PS is getting a comprehensive, coordinated and simultaneous data-set of all the physical-chemical quantities that are needed as input to the modelling tools, newly implemented by the proponents in the GAIA project, that will allow to gain information on georeferenced climatic impact of different aerosol sources and types in all sky conditions on a large latitude range.

In detail, GAIA-PS will measure the following quantities along all the path of the already planned 2024 *Polarstern* summer cruises:

Aerosol Physical Properties:

- Number size distribution data (with 8-800 nm SMPS size range and optical particle counters OPC 300-30000 nm)
- Multi-wavelength Absorption (Aethalometer) and Scattering Coefficients (Nephelometer)
- Aerosol backscatter profile and Aerosol layer height (Ceilometer)

Cloud Physical Properties:

- Cloud base height, Cloud penetration depth, cloud cover, vertical visibility (Ceilometer)

Aerosol Chemical Composition:

- Gravimetric aerosol mass (on collected samples)
- Aerosol chemical composition (ions, elements) on samples collected with a low volume sampler (every 12-24h) and with a high-time-resolution sampler (6h)
- On-line Total Carbon measurements (6h)

Radiation and Meteorological data:

- Broadband (300-3000 nm) global, diffuse and reflected irradiance and Sky Camera
- Spectral measurements (300-1000 nm) of global, diffuse and reflected irradiance
- 3D wind, temperature, humidity, pressure

Regarding sample collection, sampling strategies are modulated to fit the analytical detection limits and to capture time-spatial variations. Time and spatial data resolution is crucial for the use of the data-set with the implemented modelling tools.

Besides the environmental scientific field, this expedition is expected to have impact on Metrology: space- and wavelength-dependent multiple-scattering enhancement parameters for Aethalometer data will be assessed. Aethalometers are widely used around the globe, but

open issues concerning the corrections to be applied to the collected data still exist, preventing suitable measurement accuracy and data harmonisation.

Work at sea

A new mobile lab (GAInfrA) has been set up to be mounted on board a Research Vessel. GAInfrA instruments are placed in a half-container (Fig. 6.1) with power connections and lifting inlets for the instrumentation. The temperature of the container is controlled by an Air Conditioning inverter. The shelter and inlets have been designed to best follow the observational requirements of the main international networks for aerosol sampling (e.g. ACTRIS). PM_{10} (particles with diameter below 10 µm) inlets will be used in GAIA-PS for all the instruments as this is the most used metric and thus ensures the comparability of the acquired data withthe ones available in literature and in on-land observatories (e.g, Ny-Alesund). Further, focusing on PM_{10}, GAIA-PS data will allow GAIA to be also sensitive to those emerging natural sources that are expected to mostly contribute to the coarse mode, such as high latitude dust (dust resuspended from high latitude lands left ice-uncovered) and marine aerosol.

GAInfrA includes: 2 low-volume sequential samplers for aerosol, Aethalometer, Total carbon analyzer, Nephelometer, pyranometers (global, direct and diffuse radiation), hyperspectral radiometers (global, direct, diffuse and reflected radiation), Scanning Mobility Particle Sizer, Aerodynamic particle sizer, optical particle sizer. Meteorological sensors and radiometer will be installed on the roof of GAInfrA with a dedicated platform. A ceilometer will be also installed on board to get information on the atmospheric profiles of aerosol optical properties along the vessel cruise.

Data will be acquired and samples will be collected en-route during the already planned expeditions (aiming at having a latitude range as large as possible).

Fig. 6.1: Project rendering of GAInfrA, with the low-volume samplers in the foreground (only a few examples of the available istruments are depicted, a full list is reported in the text).

Preliminary (expected) results

The high number of samples and the detailed characterisation carried out (including markers for different sources) will guarantee high-quality results for receptor modelling. Indeed, these models require a high number of input data (to be able to catch all the possible sources) and the presence of source markers in the dataset (i.e., the model cannot catch sources for which no marker is available). As an example, the assessment of crustal elements (Al, Si, Ti, Fe), as guaranteed by the use of the analytical techinque PIXE (Particle Induced X-ray Emission), will be fundamental for mineral dust study. Sources such as high-latitude dust and long-range

transported one have similar tracers, but can be distinguished on the basis of slightly different ratios among them, due to differences in soil composition and particle size. The availability of high-time resolved samples will increase the possibility of having samples in which one of these sources (e.g. transported for a few-hour periods) is dominating, enhancing model ability to identify it. Further, the use of both chemical and optical data in the modelling process has already been shown as advantageous:

(1) to strengthen the source identification especially when relevant chemical tracers (e.g. levoglucosan for biomass burning) are not available;
(2) to give estimates for source-specific atmospheric parameters which are typically assumed a priori in other types of SA approaches (i.e. optical SA) based on optical data;
(3) to provide information on source- dependent mass absorption cross-section (MAC) values at different wavelengths for absorbing species (e.g. black carbon) (Forello et al. 2019). Indeed, the MAC depends not only on the emitted absorbing species, and it represents one of the important sources of uncertainty in models for radiative forcing estimates.

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. Further, all datasets will be stored and made available trough the CNR (http://iadc.cnr.it/cnr/) data center, which is First Level Node of the new Italian Arctic Data Center (IADC).

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

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In all publications based on this expedition, the **Grant No. AWI_PS143/2_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.

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APPENDIX

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

A.3 SCHIFFSBESATZUNG / SHIP‘S CREW

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Westphal	Matthias	DE.HSBHV	Student	Chemistry

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

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Schwarze	Stefan	Kapitän
Strauß	Erik	1.NO
Eckenfels	Hannes	1.NO / 2. NO Ladung
Weiß	Daniel	2.NO
Peine	Lutz	2.NO
Meier	Jan	Bootsmann
Buchholz	Joscha	FA/D
Burzan	Gerd-Ekkehard	FA/D
Fisahn	Paul	FA/D
Münzenberger	Börge	FA/D
Decker	Jens	FA/D
Mahlmann	Oliver	FA/D
Siemon	Leon	FA/D
Keller	Jürgen	Zimmermann
Niebuhr	Tim	FA/D (AB)
Ziemann	Olaf	LTO
Ehrke	Tom	2.TO
Krinfeld	Oleksandr	2.TO
Rusch	Torben	2.TO / 3.TO
Loew	Caspar	FA/M
Juszczyk	Michal	FA/M
Hansen	Nils	FA/M
Buchholz	Karl	FA/M
Ellner	Leopold	FA/M
Plehn	Marco	Fitter / Storekeeper
Schneider	Denise	Azubi Schiffsmechanikerin
Müller	Andreas	Kommunikations-Offizier
Pommerencke	Bernd	Elektro-Ingenieur
Zivanov	Stefan	Elektro-Ingenieur
Müller	Andreas	Elektro-Ingenieur
Krüger	Lars	Elektro-Ingenieur
Winter	Andreas	Elektro-Ingenieur
Skrzipale	Mitja	1. Koch
Fehrenbach	Martina	2. Koch
Loibl	Patrick	2. Koch
Witusch	Petra	1. Steward
Ilk	Romy	2. Steward / Nurse
Stocker	Eileen	2. Steward
Golla	Gerald	2. Steward
nicht besetzt		2. Steward
Shi	Wubo	Messe / Wäscherei
Chen	Jirong	Messe / Wäscherei
Chen	Quanlun	Messe / Wäscherei
Dr. Guba	Klaus	Schiffsarzt