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TIDAL-HX01: Trialing Innovative Data Acquisition from a Platform of Opportunity – the HX Vessel MS FRIDTJOF NANSEN

Edited by

Andreas Herber, Laura Köhler, Verena Meraldi, Katja Metfies, Melf Paulsen, Daniel Pröfrock, Tobias Steinhoff, Hongyan Xi
with contributions of the participants

HELMHOLTZ

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Titel: HX Schiff MS Fridtjof Nansen vor Island im August 2024 (Foto: Hongyan Xi, AWI)

Cover: HX Vessel MS Fridtjof Nansen off Island in August 2024 (Foto: Hongyan Xi, AWI)

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TIDAL–HX01

16 May 2024 – 18 September 2024

Reykjavik (Iceland) – Vancouver (Canada)

Chief scientist
Andreas Herber (AWI)

Coordinator
Verena Meraldi (HX)

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1. ÜBERBLICK UND EXPEDITIONSVERLAUF

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Partnerschaften mit Kreuzfahrtschiffen, insbesondere mit solchen mit Expeditionscharakter wie HX | Hurtigruten Expeditions bieten eine einzigartige Gelegenheit, wichtige Meeresdaten auf globaler Ebene zu sammeln. Da diese Schiffe durch abgelegene und unberührte Meeresgebiete fahren, sind sie als mobile Forschungsstationen ausgestattet und nutzbar. Durch die Integration spezieller wissenschaftlicher Instrumente an Bord können sie kontinuierlich wichtige ozeanographische Variablen wie Wassertemperatur, Salzgehalt, Sauerstoffgehalt, Kohlendioxidkonzentration und das Vorhandensein von Mikroplastik sowie wichtige atmosphärische Klimavariablen wie Spurengase und Aerosole, einschließlich meteorologischer Parameter überwachen.

Einer der wichtigsten Vorteile der Zusammenarbeit mit HX ist die Möglichkeit, umfangreiche Daten über große Meeresgebiete zu sammeln, die mit herkömmlichen Forschungsschiffen oft nur schwer zugänglich sind. Verschiedene geeignete Technologien, wie eDNA-Probennahme und Phytoplanktonüberwachung helfen dabei auch die biologische Vielfalt der Meere und die Gesundheit der Ökosysteme zu bewerten, die Rolle des Ozeans beim Klima zu verstehen und die Ozeanvorhersagen zu verbessern. Kreuzfahrtschiffe mit ihren regelmäßigen und vielfältigen Routen können konsistent und über einen längeren Zeitraum Daten liefern und so zur langfristigen Umweltüberwachung und zum Wissen über den Ozean beitragen. Dieser Ansatz optimiert die Ressourcen, indem er die vorhandenen Schiffe nutzt, die bereits in abgelegenen Gebieten unterwegs sind. Indem wir sie in Plattformen zur Datenerfassung umwandeln, minimieren wir den Bedarf an zusätzlichen Forschungsexpeditionen und machen den Prozess kostengünstiger und umweltfreundlicher. Ein weiterer Vorteil ist der pädagogische Nutzen für die Passagiere, die während ihrer Reise die laufende wissenschaftliche Forschung miterleben und sich daran beteiligen können. Dies trägt dazu bei, das Bewusstsein für die Bedeutung der Meeresüberwachung und der Bemühungen um den Schutz der Meere zu schärfen und den Tourismus mit nachhaltigen Praktiken und dem Einfluss auf die Gesellschaft insgesamt in Einklang zu bringen.

Zusätzlich zum touristischen Programm an Bord des HX-Schiffes MS *Fridtjof Nansen* wurde zwischen dem 16. Mai 2024 und dem 18. September 2024 ein wissenschaftliches Programm durchgeführt (TIDAL–HX01: Trialing Innovative data Acquisition from a Platform of Opportunity – like the HX vessel MS *Fridtjof Nansen*). Die Route von Reykjaviek (Island) nach Vancouver (Kanada) ist in Abbildung 1.1 dargestellt. Das Programm an Bord umfasst chemische, meteorologische, physikalische und biologische Messungen im Ozean und in der Atmosphäre. Diese Expedition leistet einen Beitrag zum AWI-Forschungsprogramm POF IV, Thema 1, 2 und 6.

Die Messungen an Bord dieses Schiffes fanden im Rahmen von „SOOP - Shaping an Ocean Of Possibilities“ statt. SOOP (https://www.soop-platform.earth/) ist eine der Innovationsplattformen im Rahmen des Innovationsplattform-Programms der Helmholtz-

Gemeinschaft Deutscher Forschungszentren, der größten Wissenschaftsorganisation in Deutschland. SOOP ist eine Technologieplattform unter Beteiligung des AWI Bremerhaven (www.awi.de/en), des GEOMAR Kiel (www.geomar.de/en) und des Hereon Geesthacht (www.hereon.de/index/php/en).

SOOP zielt darauf ab, die Ozeanbeobachtung zu verbessern, indem es die Bürger einbezieht und mit der Industrie zusammenarbeitet. SOOP aktiviert das Wissen, das Bewusstsein und das Interesse von Wissenschaft, Gesellschaft, Wirtschaft und Politik, entwickelt zuverlässige, kosteneffiziente und benutzerfreundliche, standardisierte Messsysteme und -dienste und stellt eine Datenplattform bereit, mit der Ozeandaten gesammelt, bereitgestellt und genutzt werden können.

Die folgenden Geräte wurden für den unbemannten Meßetrieb an Bord des Schiffes MS *Fridtjof Nansen* getestet:

- Contros HydroC FT (GEOMAR) – Kohlendioxid-Partialdruck des Oberflächenwassers
- Seabird SBE63 (GEOMAR) – Menge des im Meerwasser gelösten Sauerstoffs
- Seabird SBE45 (GEOMAR) – Temperatur der Meeresoberfläche
- Seabird SBE38 (GEOMAR) – Leitfähigkeit (Salzgehalt) der Meeresoberfläche
- Microplastic Sampler (Hereon) – Schwebstoffe im Ozean mit einem Durchmesser ≥10µm
- HyperSpecBox (AWI) – Optische Parameter der Absorptionseigenschaften von Phytoplankton
- eDNA-Sampling (AWI) – Parameter der marinen Biodiversität und der marinen Ökosystem-Funktionalität
- PAMOS (AWI) – Spurengase, Aerosole und meteorologische Parameter in der Atmosphäre

SUMMARY AND ITINERARY

Partnerships with cruise ships, especially those with an expedition character such as HX | Hurtigruten Expeditions, offer a unique opportunity to gather critical ocean data on a global scale. As these vessels travel through remote and pristine marine environments, they are equipped to act and be used as mobile research stations. By integrating specialized scientific instruments onboard, they can continuously monitor essential oceanographic variables such as water temperature, salinity, oxygen levels, carbon dioxide concentration and the presence of microplastics, as well as essential climate variables such as trace gases and aerosols, including meteorological parameters.

One of the key benefits of the collaboration with HX is the ability to collect extensive data across large oceanic areas that are often difficult to access with traditional research vessels. Various suitable technologies such as eDNA sampling and Phytoplankton monitoring help also assess marine biodiversity and ecosystem health, understand the ocean's role in climate, and improve ocean forecasts. Cruise ships, with their regular and diverse routes, can deliver data consistently and over time, contributing to long-term environmental monitoring and ocean knowledge. This approach optimizes resources by leveraging existing vessels already operating in remote areas. By converting them into data-collection platforms, we minimize the need for additional research expeditions, making the process more cost-effective and environmentally friendly. An additional advantage is the educational benefit for passengers, who can witness and paticipate in ongoing scientific research during their journey. This will help raise awareness about the importance of ocean monitoring and conservation efforts, aligning tourism with sustainable practices and overall societal impact.

In addition to the tourist program on board the HX vessel MS *Fridtjof Nansen*, a scientific program was carried out between 16 May 2024 and 18 September 2024 (TIDAL–HX01: Trialing Innovative data Acquisition from a Platform of Opportunity – like the HX vessel MS *Fridtjof Nansen*). The route from Reykjaviek (Iceland) to Vancouver (Canada) is shown in Figure 1.1. The onboard program includes chemical, meteorological, physical, and biological measurements in the ocean and the atmosphere. This expedition contributes to the AWI research program POF IV, Topic 1, 2 and 6.

The measurements on board this vessel took place within the framework of "SOOP – Shaping an Ocean Of Possibilities". SOOP (https://www/soop-platform/earth/en/homepage-2/) is one of the innovation platforms from the Innovation Platform programme of the Helmholtz Association of German Research Centres, the largest scientific organization in Germany. SOOP is a technology platform with the participation of AWI Bremerhaven, (www.awi.de/en), GEOMAR Kiel (www.geomar.de/en) and Hereon Geesthacht (www.hereon.de/index/php/en).

SOOP aims to improve ocean observations by engaging citizens and collaborating with industry.

SOOP activates the knowledge, awareness and interest of science, society, business and politics; develops reliable, cost-efficient and user-friendly, standardized measurement systems and services; provides a data platform with which ocean data can be collected, made available and useed, and establishes an innovation-based value creation to strengthen ocean observation.

The following devices were tested for unmanned operation aboard of the MS *Fridtjof Nansen*:

- Contros HydroC FT (GEOMAR) – surface water carbon dioxide partial pressure
- Seabird SBE63 (GEOMAR) – amount of oxygen dissolved in the seawater
- Seabird SBE45 (GEOMAR) – sea surface temperature
- Seabird SBE38 (GEOMAR) – sea surface conductivity (salinity)
- Microplastic Sampler (Hereon) – suspended solids in the ocean with diameter ≥ 10 µm
- HyperSpecBox (AWI) – optical data on the phytoplankton optical properties (absorption and attenuation)
- eDNA Sampling (AWI) – parameter of marine biodiversity and ecosystem functionality
- PAMOS (AWI) – trace gases, aerosol and meteorological parameter in the atmosphere

Abb. 1: Fahrtverlauf der MS Fridtjof Nansen (TIDAL-HX01) von Reykjavik nach Vancouver, siehe https://doi/pangaea/de/10/1594/PANGAEA/973412 für eine Darstellung des master tracks in Verbindung mit Messaktivitäten für TIDAL-HX01

Fig. 1: Cruise track of MS Fridtjof Nansen (TIDAL-HX01) from Reykjavik to Vancouver, see https://doi/pangaea/de/10/1594/PANGAEA/973412 to display the master track in conjunction with the list of the measuring activity of TIDAL-HX01

2. WEATHER CONDITIONS DURING TIDAL-HX01

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The expedition was carried out from mid May to mid September 2024 and covered different areas. To start, MS *Fridtjof Nasen* circumnavigated Iceland three times between 16 May and 9 June 2024 with Reykjavik as a start and ending point. The daily maximum temperature varied between 6°C and 16 °C and the night temperature between 2°C and 10°C. With exception of end of May (24 – 28 May 2024) the observed temperature was in the typical temperature range of the last 30 years. An example of the weather conditions is shown below for the first circumnavigation from 16 to 24 May 2024. We started the measuring activity on 16 May 2024, as a typical Icelandic cloudy day, expected weather situation during early summer with 10°C. The MS *Fridtjof Nansen* arrived in Reykjavik after the circumnavigation in the moning of 24 May 2024. This was a rainy day with 10°C during noon.

- 17 May 2024: Snaefellsnesspeninsula – it was cold and windy, but partly sunny
- 18 May 2024: Patreksfjördur – during the night the wind became colder
- 19 May 2024: Holmavik – the weather continued to be cold and windy
- 20 May 2024: Akureyri – winter-like weather with snow-powdered landscape
- 21 May 2024: Husavik – strong winds and storms, like the last days – no weather improvement
- 22 May 2024: Bakkagerdi – a real sunny day without wind
- 23 May 2024: harbour of Heimaey – also nice weather conditions – a sunny day again

The second part of the northern tour of the MS *Fridtjof Nansen* consisted of four trips to Ilulissat between 9 June and 8 August 2024, again with Reykajvik as a start and ending point. As example here the temperature information during this period at Qaqortoq. The daily maximum temperature varied between 9°C and 20 °C and the night temperature between 4°C and 9°C. The temperature variation was in the long-term temperature range over the last 30 years. An example of the weather conditions is shown below for the last cruise from 23 July to 8 August 2024. During this voyage we also carried out meteorological observations as part of the operation with the PAMOS (Portable Atmspheric mmeasuring Box On Sea) The preliminary results can be seen in Figure 9.2, showing temperature and huminidy records during this journey. The journey began on 24 July 2024 in a very Icelandic manner with sideways rain, gusty winds and rather chilly temperatures and ended upon arrival in Reykjavik in the moning of 8 August, with a cloudy day and a temperature of 12°C during noon.

- 25 July 2024: Irminger Sea – cloudy skies and slightly stormy seas
- 26 July 2024: Irminger Sea – sunny day and calm sea
- 27 July 2024: Qaportoq – clouds have lifted and partly sunny

- 28 July 2024: Kvanefjord – after fog pulled away, a nice partly sunny day
- 29 July 2024: Maniitsoq – heavy fog does not lift and is accompanied by rain and swell
- 30 July 2024: Sisiomiut – cloudy in the morning, by the early afternoon the sun came back
- 31 July 2024: Ilulissat – foggy in the morning and blue sky in the afternoon
- 1 August 2024: Vaigatsund – extremely foggy with almost zero visibility
- 2 August 2024: Evighed Fjord – a sunny day with blue sky
- 3 August 2024: Nuuk – foggy morning again, but sunny and warm in the afternoon
- 4 August 2024: Ivituut – after the fog disappeared a sunny and warm day again
- 5 August 2024: Prins Christian Sund / Appilattoq –nice weather with blue sky and no wind
- 6 August 2024: Irminger Sea – slightly stormy sea, but partly patches of blue sky
- 7 August 2024: Irminger Sea – increased stormy sea and cloudy

We stopped the measuring activity on 13 August 2024 upon arrival in Nuuk (Greenland). During the third and the fourth parts of the expedition, the Northwest Passage and Alaska, unfortunately no measuring activities were caried out due to unability to obtain a permit (Diplomatic Notification from Canada and the USA) to operate within the Canadian and US Exclusive Economic Zone (EEZ), therefore the weather information was not relevant for our activity and for the report.

3. INTRODUCTION OF HX AND MS FRIDTJOF NANSEN

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Since 1896, HX | Hurtigruten Expeditions (www.travelhx.com / 210 Pentonville Rd., London, N1 9JY, UK) has been taking curious travellers on mindful expeditions to the most remote and awe-inspiring places on the planet. HX is a member of the Association of Arctic Expedition Cruise Operators (AECO) and of the International Association of Antarctica Tour Operators (IAATO). More details you can find under: https://www.hurtigruten.com/group/about/history/.

HX's Science & Education Program gives guests the opportunity to take part in an immersive, hands-on, educational experience to get a better understanding of the environment they visit with HX and increase awareness on the challenges impacting these ecosystems, such as climate change, by focusing on science, education and sustainability. An important part of our Science & Education Program is the support provided to the scientific community by offering our ships as platform of opportunity and facilitating important sample and data collection in remote, understudied areas. HX guests also benefit from the presence of researchers by having the opportunity to interact with themin person and see them at work.

The main operation areas are the Polar areas (Antarctica and the Arctic including Iceland, Svalbard, Greenland, Northwest Passage and Alaska), coasts of South America and the Galapagos-Islands. Presently HX operates five vessels, the MS *Fridtjof Nansen*, the MS *Roald Amundsen*, the MS *Fram*, the MS *Spitzbergen*, and the MS *Santa Cruz II*.

During the Expedition TIDAL-HX01, the MS *Fridtjof Nansen* was used as platform for the scientific program. As introduction to the vessel, Figure 3.1 shows the onboard Science Center located at the heart of the ship on deck 6 and Figure 3.2 offers an aerial view of the ship operating in Polar waters. The MS *Fridtjof Nansen* was built by Green Yard Kleven at its Kleven Yardsin Ulsteinvik, Norway and started operating in June 2020. The *Fridtjof Nansen* is a hybrid-powered ship running on Marine Gas Oil (MGO). The hybrid propulsion system integrates diesel engines and battery units to reduce fuel consumption by approximately 20% and carbon dioxide (CO_2) emissions by 20%. Specific information on the MS *Fridtjof Nansen* (technical parameters) can be found in Table 3.1.

Tab. 3.1: Technical parameters of the MS *Fridtjof Nansen*

Parameter	**Information on it**
Cross tonnage of the vessel	20889 tons
Length of the vessel	140 m
Beam of the vessel	23,6 m
Speed of the vessel	15 knots
Used fuel for operation	Marine Gas Oil / electric power
Passender Capacity of the vessel	490
Crew members of the vessel	150

HX's Expedition teams are composed of permanently employed staff, led by a Science & Education coordinator who is in charge of putting the best education program together for each trip. HX employs experts on several relevant areas such as ornithology, history, marine biology, environmental sciences, geology. This permanent team is supplemented with regional experts. The Expedition Team members come from all over the world and from all walks of life. They are a wonderful mix of youth and maturity, unique interests, and colourful backgrounds. But what they all have in common is a passion for travel, a love of our planet, and a desire to share their knowledge. Together, they will enhance the guests' experience.

Adventurers in their own right, the Expedition Team have decades of exploration knowhow and are experts on the destinations. Some are Arctic Nature Guides or rangers; others have worked as ecologists on remote research and conservation projects; all are well-versed in AECO and IAATO guidelines. Each team member is deeply committed to sustainability and trained to safeguard our guests, the wildlife, and the fragile habitats HX explores, see https://www.travelhx.com/en/stories/experts-in-exploration/.

HX offers its vessels as platforms of opportunity to the Scientific community and has established a number of collaborations with research institutions and NGOs worldwide. HX's Science & Education Program focuses on delivering an immersive educational experience to guests; the combination of lectures and science focused activities help guests to get a better understanding of the world: from researching the impact of climate change on animal populations and sea ice to getting a better understanding of migratory patterns of marine life. The Science Centres provide a unique opportunity to genuinely engage with guests and deepen their learning through hands-on, immersive experiences. They are also a place for our scientists and visiting researchers to work – for instance by preparing newly collected samples for transport or storage. In addition to the science equipment, the Science Centers also include museum-type collections, a small library, and speciality areas for workshops in biology, photography, arts and crafts, and more, https://www.travelhx.com/en/stories/science-and-education-program/.

Fig. 3.1: The science center of the MS Fridtjof Nansen (www.travelhx.com)

Fig. 3.2: A nice view of the Fridtjof Nansen (aerial photo © Espen Mills, HX)

4. OVERVIEW ON THE MEASUREMENT ACTIVITIES

Tobias Steinhoff [1], Melf Paulsen [1], Myriam Dutzi [1]
Ann-Cathrin Rohrweber [2], Lars Hildebrandt [2]
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The entire voyage for the collection of oceanic and atmospheric measurements with the MS *Fridtjof Nansen* was planned from 16 May to 18 September 2024 and the overall trip was split into four sections, starting with three Iceland circumnavigations, followed by four trips to Disco Bay and Western Greenland, a transit through the Northwest Passage and finally the journey from Nome, Alaska through Canadian Pacific waters up to Vancouver. For the first two sections we were permitted (Diplomatic Notofication) by Iceland and Denmark to carry out measurements within their Exclusive Economic Zone (EEZ). For the last two sections, the Northwest Passage (Canada), Alaska (USA) and up to the Canadian Pacific aera we were not granted a permit and stopped therefore the measurirng activity before entering the Canadian Arctic. Therefore, the last measurements were carried out on 13 August 2024 upon arrival in Nuuk (Greenland). The route around Iceland (Circumnavigation) and also the route along the western coast of Greenland started and ended in Reykjavik. Figure 4.1 summarizes the measurement activities with the different oceanic and atmospheric systems during the complete journey. During the last sections from Nome (USA) to Vancouver (Canada) only some technical checks were done before we dismantled some devices from the underway systems.

Cruise [Reykjavik, Iceland – Vancouver, Canada]	Travel time	Scientific measurements of oceanic and atmospheric parameter					Onboard measurements carried out (or cared for) by	
		(pCO₂, oxygen temperature, salinity)	HyperSpecBox (hyperspectral measurements)	Atmospheric Box PAMOS	Microplastic Sampler	eDNA Sampler		
FNICE2412	16/05/2024 – 24/05/2024	↓	↓				Hongyan Xi	
FNREY213	24/05/2024 – 01/06/2024	↓				↓	Julian Mai	
FNREY2414	01/06/2024 – 09/06/2024	↓			↓		Lars Hildebrandt	
FNGRE2415	09/06/2024 – 24/06/2024							*"Unclear status of notification"*
FNGRE2516	24/06/2024 – 09/07/2024	↓					Tobias Steinhof	
FNGRE2517	09/07/2024 – 24/01/2024	↓			↓		Ann-Cathrin Rohrweber	
FNGRE2518	24/07/2024 – 08/08/2024	↓		↓	↓		Laura Köhler / Andreas Herber	
FNNWP2519	08/08/2024 – 02/09/2024	↓						MV Fridtjof Nansen engine crew*
FNALA2520	02/09/2024 – 18/09/2024						Julian Mai	

Fig. 4.1: Measurement activities on board of the MS Fridtjof Nansen during the HX voyages from 16 May to 18 September 2024 (the meaurements were stopped on 13 August 2024 in Nuuk)*

Within the framework of the innovation platform “SOOP” we installed instruments to carry out measuring various parameters of the surface water, on board of the MS *Fridtjof Nansen*. The underway inline system, installed in the auxiliary engine room (deck 1) integrates different instruments, that can be operated in the flowthrough mode. During the voyages from 4 May to 16 May 2024 from Hamburg (Germany) to Reykjavik (Iceland) this underway measuring platform was installed by the colleagues from GEOMAR, Melf Paulsen, and Myrian Dutzi. Myriam Dutzi was also involved in the Public Relation activity for the entire voyages. The atmospheric system PAMOS was installed and tested end of July / beginning of August during one of the cruises along the Greenland West coast, see chapter 9.

Figure 4.2 shows a schematic of the installation. It is connected to a bypass for the ship’s clean water generator. The whole installation can be isolated by closing valves 1 and 10 (Figure 4.2). Only when the ship is underway (and regulations allow) the system is turned on. When activated, the two pneumatic ball valves (2) open and the pump (4) turns on and supplies water to the different instruments. Close to the intake a temperature sensor is installed (3) to record the surface ocean temperature as close as possible to the inlet. The system has four separate lines for different instruments, so that they can be operated independently. Figure 4.3. shows the final installed underway measuring platform in the auxiliary engine room on deck 1.

Surface water is continuously taken from the ship’s water intake in approximately 5 m depth at a flow rate of approximately 100 l/min. The water is pumped through different instruments to measure various parameters (Figure 4.2), and then pumped back outside after passing through the instruments. The water is not contaminated with any chemicals or other substances. Some measurements need reference measurements. For this purpose, a small amount of surface water will be collected in sample containers for analysis in the laboratories at land.

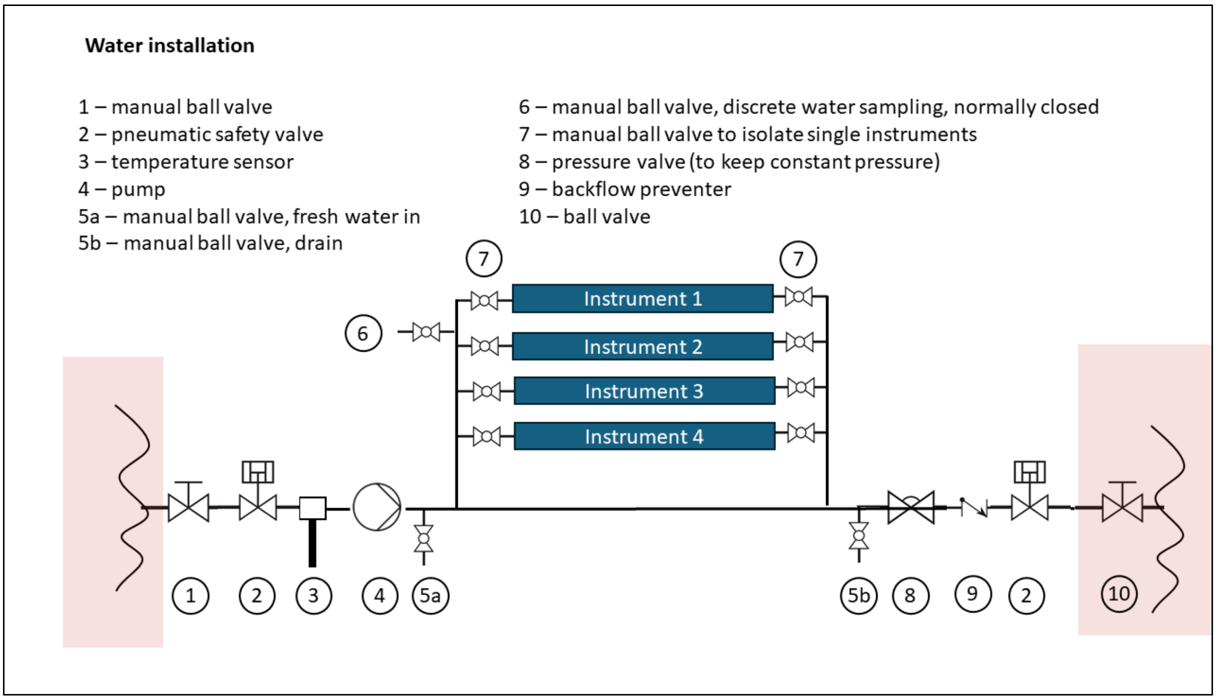

Fig. 4.2: Schematic of the underway installation on board the MS Fridtjof Nansen

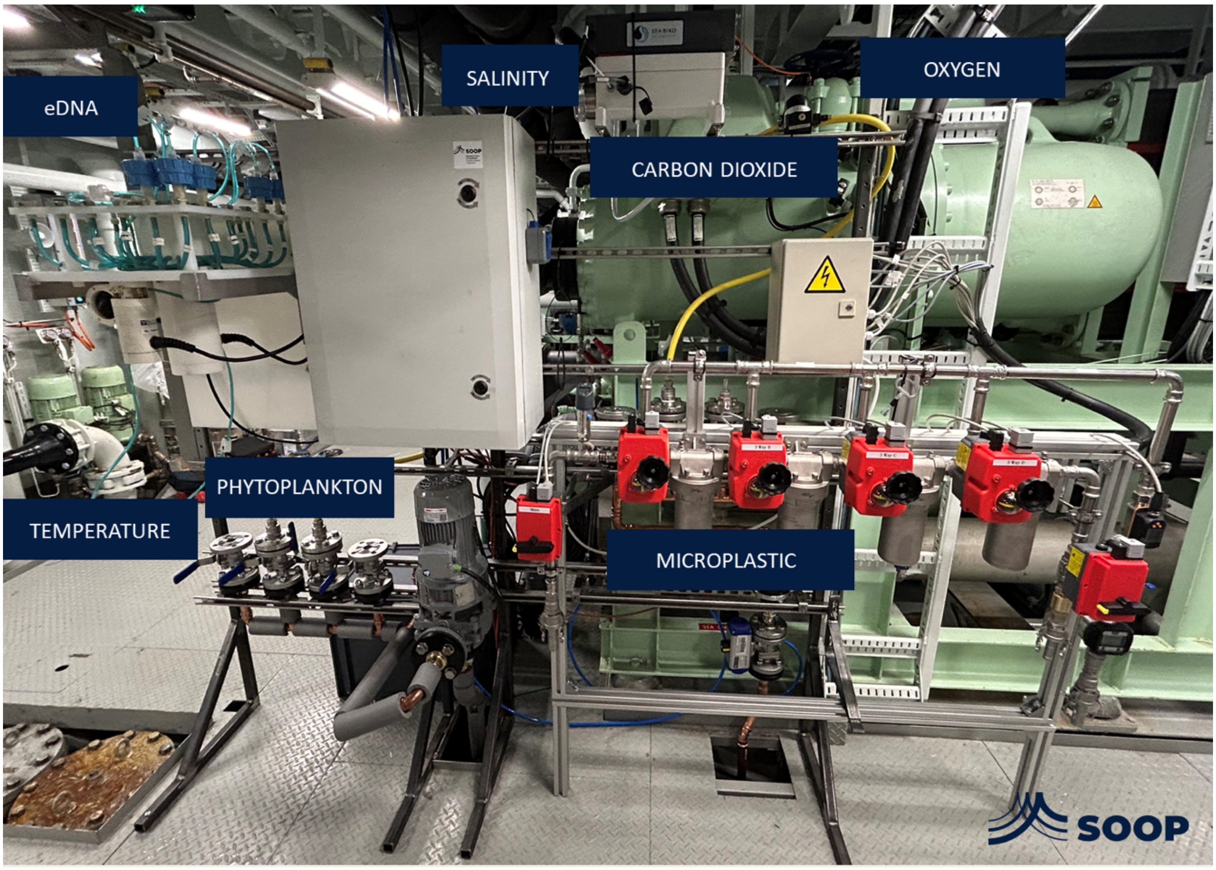

Fig. 4.3: The underway measuring platform in the auxiliary engine room (deck 1)

5. GEOMAR

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Outline

Within the SOOP operations onboard we installed biogeochemical instruments for continuous underway sampling. The sensors measure temperature, salinity, dissolved oxygen (DO) and partial pressure of CO2 (pCO2) in the surface water. The instruments are part of an installation in the auxiliary engine room (deck 1) of the expedition vessel MS *Fritdjof Nansen*. Surface water is continuously pumped through the instruments whenever the ship is at sea.

Objectives

Temperature and salinity together with the position are basic parameters that are needed for any oceanographic data interpretation, while the measurements of DO and pCO2 allow a closer look into the water's biogeochemical characteristics. The ocean absorbs up to 25% of the annual CO2 emissions (Friedlingstein et al., 2023) and thus plays a vital role in the global carbon cycle. The annually published Global Carbon Budget (Friedlingstein et al., 2023) uses data from so called Ships-Of-Opportunity like the MS *Fridtjof Nansen* to estimate the ocean carbon sink. This estimate strongly depends on data from all regions of the ocean. While parts of the ocean along the main shipping routes (e.g. between Europe and North America, between North America and Asia) are well observed the community is lacking data from remote areas like the high latitudes. In addition, the ocean carbon sink is highly variable in time and space and especially dynamics from coastal regions can vary by a factor of two over the course of days and months. Therefore, SOOP aims to outfit numerous platforms with such instruments to improve our understanding of these dynamics.

Work at sea

The biogeochemical instruments package included four different instruments measuring parameters in the surface water:

- Seabird SBE45 and SBE38 (Temperature and Salinity): The water temperature was measured as close to the water inlet as possible and again close to the setup of the other instruments where also salinity was measured.
- 4H-Jena Contros HydroC-FT (pCO2): While the seawater is pumped through the instrument it is passing a membrane. The membrane allows gases that are dissolved in the water to pass through it, without letting the water through. This way the same number of gases will be present on the water side and air side of the membrane. The air side is measured using an infra-red detector for its CO2 content. The water was not altered.

- Seabird SBE63 (DO): The seawater is passing a membrane and dissolved oxygen is dissolving in a foil that is constantly exposed to the water. The amount of oxygen dissolved in the foil is equivalent to the amount of oxygen dissolved in the seawater. The oxygen in the foil changes its structure, which can be measured by diodes.

All data were recorded in 1-minute intervals and data for position were added. As mentioned above, temperature and salinity data are used as basic oceanographic data. These data can be used to identify different water masses and structures (e.g. fresh water input from ice). Together with the pCO2 data, DO data can be used to estimate biological productivity. With this information it is not only possible to determine CO2 fluxes between the atmosphere and the ocean but also investigate the driver. This enhances our understanding of these dynamic processes in remote areas.

Preliminary (expected) results

The instruments were measuring whenever the ship was cruising, recording valuable data in remote areas. The preliminary summarized results for the period from 16 May up to 13 August 2024 you can see in Figure 5.1 (temperature and salinity in the surface water) and in Figure 5.2 (dissolved oxygen and partical pressure of CO2 in the surface water). Only during the voyage from 9 to 24 July 2024 no measurements were performed due to unclear situation on the permit in the Greenland EEZ. The raw data need to be processed before they can be used for biogeochemical analysis. The instruments were sent back to GEOMAR Helmholtz Centre for Ocean Research Kiel in Germany for calibration and maintenance in October 2024. Once the data are in a final state, they will be published in the "Surface Ocean Carbon Dioxide Atlas" (SOCAT, www.socat/info) which is described in the data management.

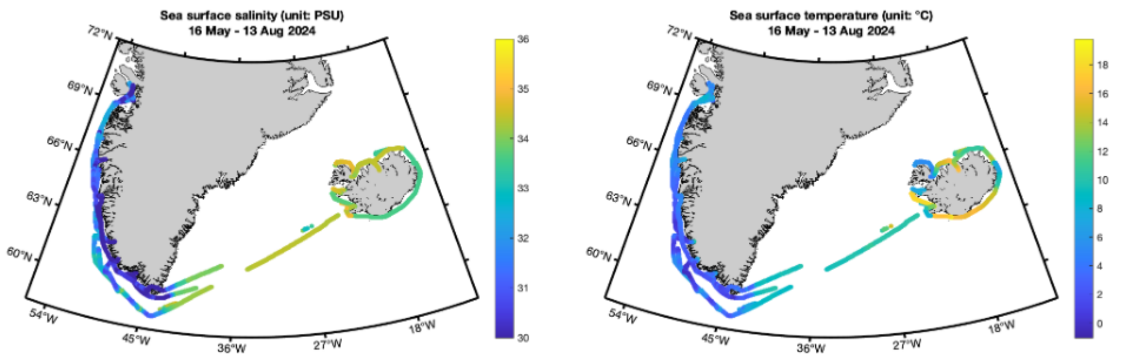

Fig. 5.1: Preliminary summarized results for the period from 16 May up to 13 August 2024 for temperature and salinity in the surface water

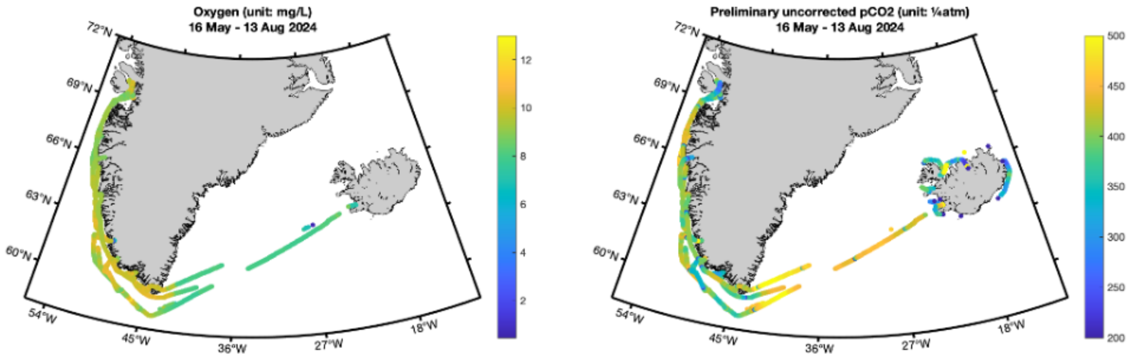

Fig. 5.2: Preliminary summarized results for the period from 16 May up to 13 August 2024 for dissolved oxygen and partial pressure of CO_2 in the surface water

Data management

The data processing is a time-consuming step and will be finalized before March 2025. The processed 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. Given that the quality of the data deemed acceptable, the data will be submitted to “SOCAT - Surface Ocean CO2 Atlas” (www.socat.info).

This expedition was supported by the Helmholtz Research Programme "SOOP – Shaping an Ocean Of Possibilities”, see https://www.soop-platform/earth/en/homepage-2/) one of the innovation platforms, as part of the Helmholtz Innovation Platform programme, funded from the “Pakt für Forschung und Innovation”.

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6. SOOP – MICROPLASTIC SAMPLER

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Outline

As part of the SOOP operation on board of different vessels sampling of microplastics (MPs) from the water phase is crucial. MPs are contaminants of emerging concern and have been found in habitats across the globe from deep-sea sediments to remote mountain regions. MP particles and fibers can cause direct effects (e.g. blockage of different *lumen* or inflammation), and absorb and release toxic organic chemicals and heavy metals. MPs can originate from the fragmentation of larger debris items induced by photodegradation, mechanical stress, hydrolysis and biofouling or be released as primary MPs from cosmetics, paints etc. A schematic overview of transport processes and pathways of macroplastic waste and MPs into and within marine environments is shown in the Figure 6.1, see https://www.microplastic-compendium.eu, 10/2024.

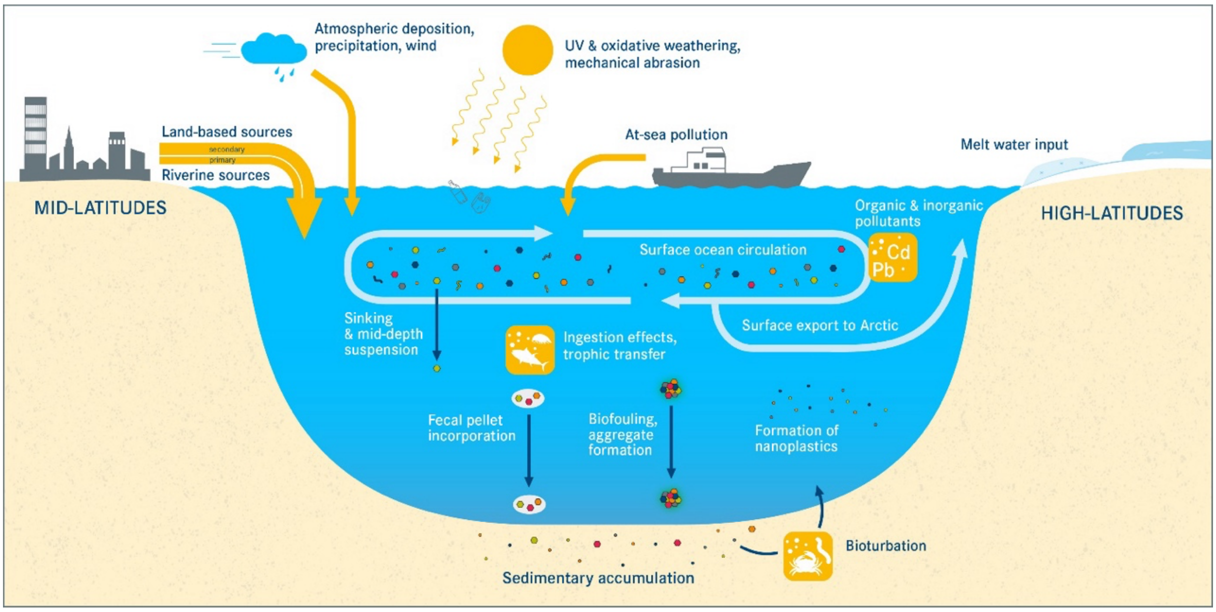

Fig. 6.1: Schematic overview of transport processes and pathways of macroplastic waste and MPs into and within marine environments (https://www.microplastic-compendium.eu, 10/2024)

Objectives

The SOOP Microplastic Sampler collects and enriches all suspended solids with $d_{SPM} \geq 10$ µm from the water phase using automatically switchable ball valves (Hansen et al., 2023; Hildebrandt et al., 2022).

The aim is to collect MPs from the water phase for subsequent particle analysis in the laboratory using quantum-cascade-laser-based microspectroscopic techniques (particle sizes, shapes and polymer types). Volume-reduced sampling, whereby approximately 1 - 10 m^3 are filtered, allows a representative statement to be made about the MP number concentrations and distribution in the investigated area. Fractionation into particle size classes according to diameter is carried out by successive use of 300 µm, 100 µm and 10 µm filter cartridges.

Work at sea

The SOOP Microplastic Sampler was installed in the auxiliard room on deck 1 of the MS *Fridtjof Nansen*. Figure 6.2 shows the analytical process from sampling on board the MS *Fridtjof Nansen* up to the final analysis in the laboratory. Table 6.1 contains specific information about the application of the sampling system.

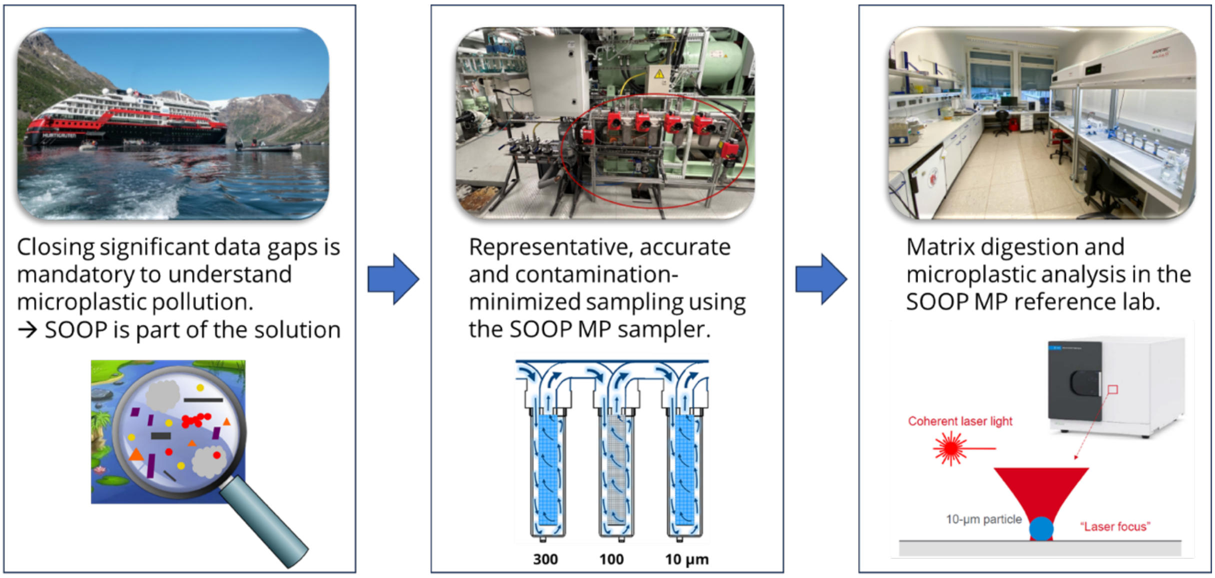

Fig. 6.2: The analytical process from sampling on board the MS Fridtjof Nansen to the final analysis in the laboratory

Tab. 6.1: Excerpt from the Sampling documentation

Cruises	Sampling No	Date [DD/MM/YYYY	Start time [UTC]	End time [UTC]	Volume [L]	Number oif samples [cumulated]
Reykjavik – Reykjavik [circumnavigate Iceland]	1	02/06/2024	15:55	17:57	1738.40	3
	2	04/06/2024	00:26	01:33	1428.0	6
	3	04/06/2024	16:00	19:02	852.60	9
	4	07/06/2024	23:49	00:28	837.00	11
Reykjavik – Greenland – Reykjavik	5	10/07/2024	19:10	23:10	1466.00	14
	6	13/07/2024	10:35	12:30	711.00	17
	7	14/07/2024	22:58	02:09	1218.00	20
	8	17/07/2024	16:25	18:46	1748.00	23
Reykjavik – Greenland – Reykjavik	9	30/07/2024	16:23	18:40	2031.00	26
	10	30/07/2024	11:12	13:52	2280.00	29
	11	04/08/2024	12:04	14:57	2128.00	32

Preliminary (expected) results

The first aim was to test the SOOP Microplastic Sampler under real environmental conditions on bord of a commercial vessel, which has never been done before. All tests regarding critical parameters such as pressure, throughput, tightness, robustness of the automated valves, handling of cartridge filters was successful. 32 samples were collected which is a high number in the context of highly complex MP analysis. In Figure 6.3 you can find the overview on the sampling during three voyages - the analytical process from sampling on board the MS *Fridtjof Nansen*. The final analysis is planned within the next months in our SOOP Microplastic Reference laboratory. The data generated from our group will make an invaluable contribution to understanding global MP pollution (fate, transport, fragmentation etc.).

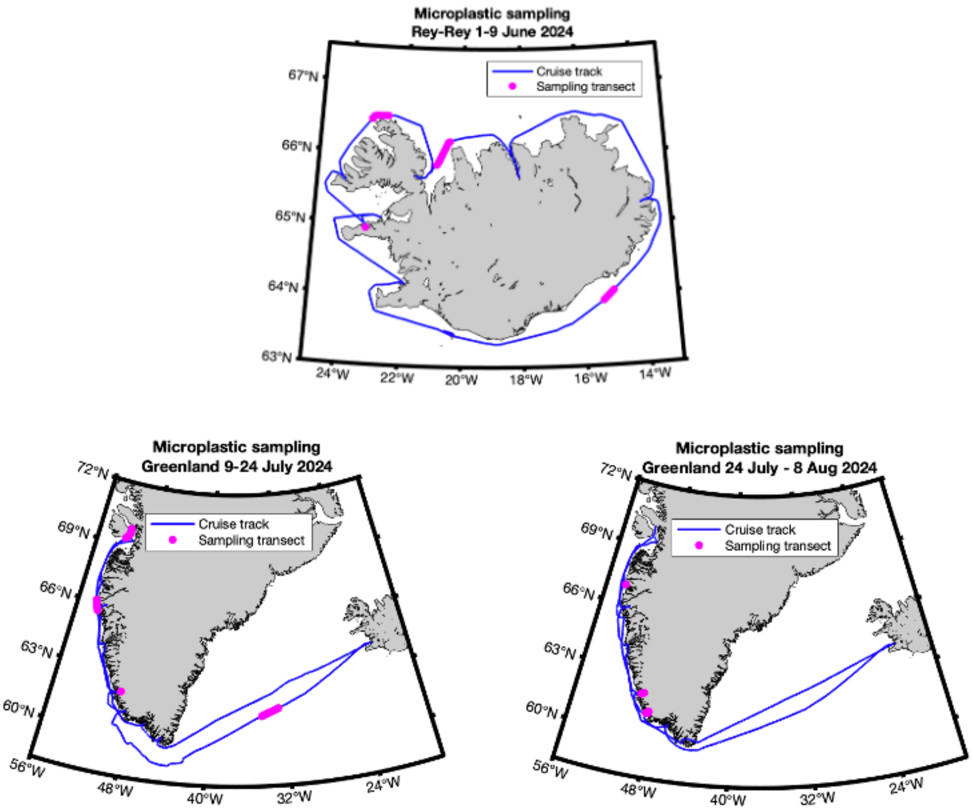

Fig. 6.3: Overview on the sampling during three voyages - the analytical process from sampling on board the MS Fridtjof Nansen to the final analysis in the laboratory

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 4.0 license will be applied. The data will be available also under the Hereon HCDC data base (https://www.hereon.de/central_units/hcdc/index.php.de).

This expedition was supported by the Helmholtz Research Programme "SOOP – Shaping an Ocean Of Possibilities", see https://www.soop-platform/earth/en/homepage-2/) one of the innovation platforms, as part of the Helmholtz Innovation Platform programme, funded from the "Pakt für Forschung und Innovation".

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Hildebrandt, L, El Gareb F, Zimmermann T, Klein O, Kerstan A, Emeis K-C, Pröfrock D (2022) Spatial Distribution of Microplastics in the Tropical Indian Ocean Based on Laser Direct Infrared Imaging and Microwave-Assisted Matrix Digestion. Environmental Pollution 119547.

7. SOOP – HYPERSPECBOX

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Outline

As part of the SOOP operation on board of different vessels, we collected data on phytoplankton diversity and abundance in the vast ocean is essential. Phytoplankton in the sunlit layer of the ocean contribute approximately 50% to global primary production. They act as the base of the marine food web fueling fisheries, and also regulate key biogeochemical processes such as exporting carbon to the deep ocean. Phytoplankton contain various groups that function differently in the marine ecosystem. Climate-induced changes causing temperature rise, ocean acidification and ocean deoxygenation stress the ocean's contemporary biogeochemical cycles and ecosystems, thereby impacting the phytoplankton communities. Related to this, the changing nutrient and light availability is also critical for the development of phytoplankton communities. With the HyperSpecBox installed on different commercial vessels, such as cruise and container ships, that travel all around the global ocean, we can fill the gaps resulting from limited coverage from research vessels and ocean color remote sensing on phytoplankton community composition. The final combined global data set will enable much better assessment of the status and change not only of the phytoplankton diversity, but of the marine ecosystem and of ocean biogeochemical fluxes which can make a step-change in assessing feedback to climate change and in applications of marine services.

Objectives

The HyperSpecBox is a measurement system with the main component AC-S (Spectral Absorption and Attenuation Sensor), see designed as a flow-through inline system on various platforms such as moving vessels at sea (see Figure 7.1 left panel). By measuring how much of the light is absorbed and scattered by phytoplankton particles in the surface layer of the ocean, the HyperSpecBox provides us continuous high-resolution measurements of optical data on the phytoplankton absorption properties in the visible to near infrared range, which enable us to quantify through our specific retrieval the chlorophyll a concentration (Chl-a) of various phytoplankton groups, besides the total Chl-a, along the ships transects.

Work at sea

The HyperSpecBox was operated during the journey of the MS *Fridtjof Nansen* around the coast of Iceland from Reykjavik and back to Reykjavik (16 – 24 May 2024). It was installed in the vessel's auxiliary engine room (deck 1) and integrated into the inline system (also used by the other SOOP instruments) with pumped seawater flowing through (Figure 7.1 right panel). While the ship was steaming, the HyperSpecBox was running continuously and collecting the VIS-NIR spectra at 4 Hz frequency. Its operation was only shut off (flushed with fresh water) while the ship was anchored in the sea over two hours or docked at the port. The device was cleaned daily in these coastal waters with high productivity to prevent contamination of the sensor by biofouling. The SOOP inline system on board also provided measurements of temperature and salinity (chapter 5, see Figure 5.1 - GEOMAR dataset) which were used for the HyperSpecBox data post-processing to obtain the absorption spectra of the marine particles (Liu et al., 2018), from which finally the Chl-a concentration of all and different groups of phytoplankton are derived using our own-developed algorithm based on empirical orthogonal function analysis (Bracher et al., 2020).

The HyperSpecBox measurements collected during the cruise include raw data of light absorption and attenuation coefficients over the visible-NIR range of 380–750 nm with ~ 3/3 nm sampling resolution without and with being filtered through a 0/2 µm filter cartridge to separate the absorption signal from particles and colored dissolved organic matter. The processed data of absorption spectra of particles is shown in Figure 7.2.B). The final derived products of the Chl-a concentration of all and of five phytoplankton groups including diatoms, haptophytes, dinoflagellates, green algae and prokaryotic phytoplankton it can beseen additional in Figure 7.2.C.

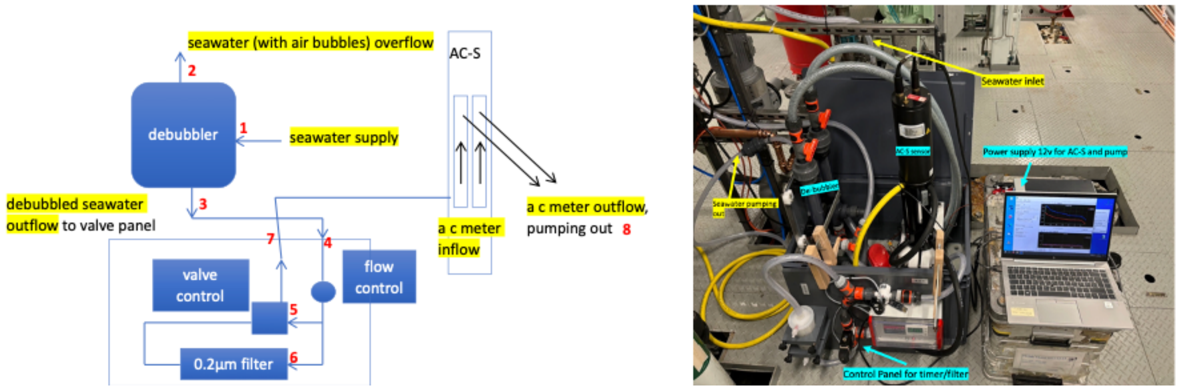

Fig 7.1: Conceptual structure of the HyperSpecBox (left side) and its installation on board of the MS Fridtjof Nansen (righ side)

Preliminary (expected) results

During the MS *Fridtjof Nansen* journey, after the initial installation, troubleshooting and adjustment with the tubing and connection of the HyperSpecBox, the instrument started to collect data regularly since the night of 17 May 2024. Measurements were stopped at 4 am on 24 May 2024 upon arrival at the Port in Reykjavik. The HyperSpecBox was then dissembled and packed for further operation on an AWI Expedition in the Arctic in June 2024.

During the 8-day expedition, we were able to collect data in a high temporal resolution along the cruise track around the whole Iceland coast (Figure 7.2.A). Figure 7.2.B shows the particulate absorption spectra obtained after processing the raw data of the attenuation and absorption signals recorded by the HyperSpecBox. Particulate absorption data were binned to 1 min and then used as input to the model for phytoplankton (group) Chl-a projection. Figure

7.2.C shows the distribution of Chl-a concentration of all and of the different phytoplankton groups along this cruise. These preliminary results indicate clearly that the variability in TChl-a, and Chl-a of diatoms, and dinoflagellates in different coastal regions of Iceland is much higher than for green algae and haptophytes, whereas prokaryotic phytoplankton show in general very low concentrations all around the island. Further analysis is necessary to finalize the data quality control and to intercompare also the HyperSpecBox data set versus the results from the other parameters collected by the SOOP inline system.

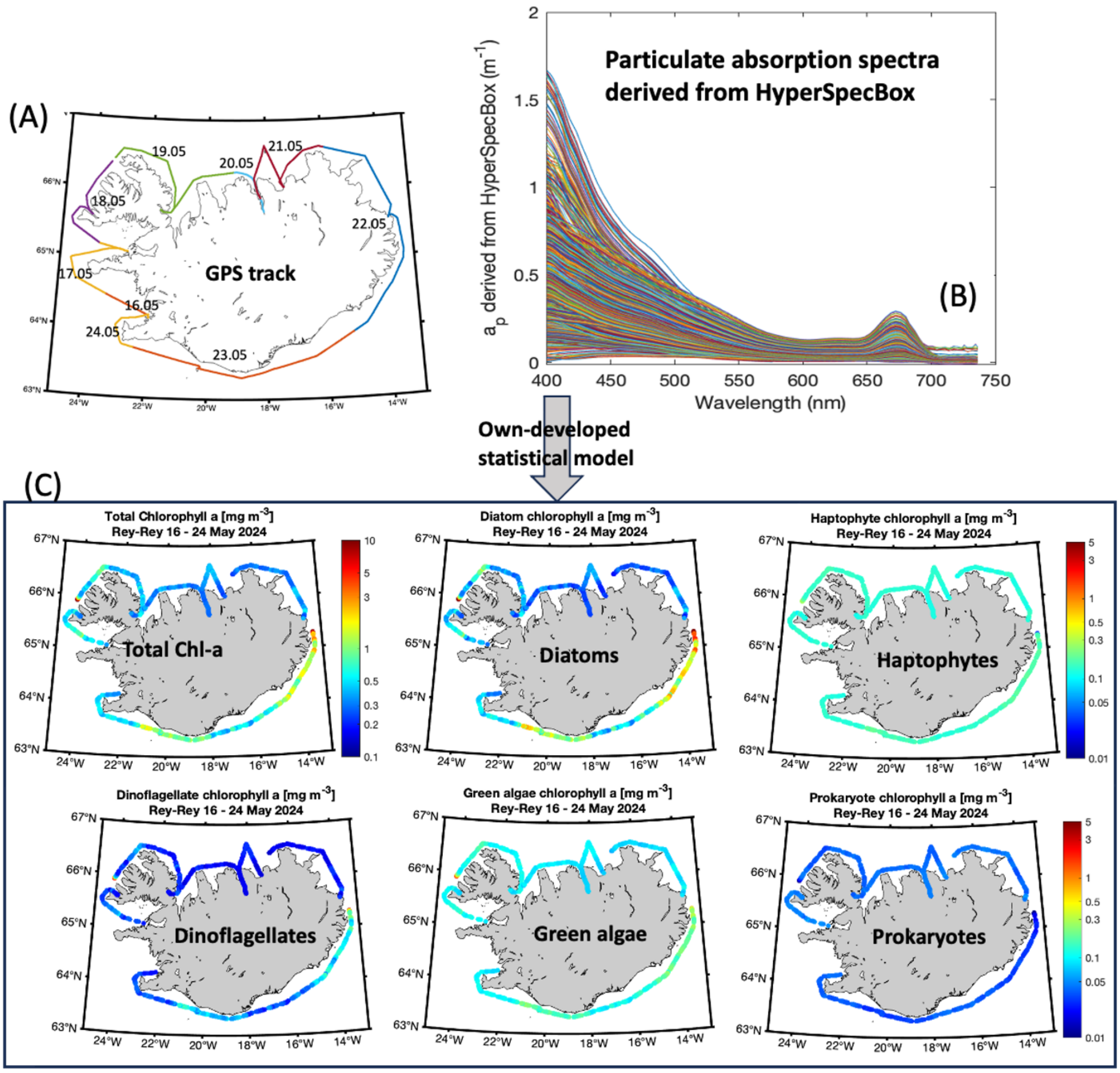

Fig 7.2: High temporal resolution data along the cruise track around the whole Iceland Circumnavigation; a) the GPS track b) absorption spectra of particles derived from HyperSpecBox c) concentration of total chlorophyll, diatoms, haptophytes, dinoflagellates, green algae and prokaryotic phytoplankton

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the expedition at the latest. By default, the CC-BY 4.0 license will be applied.

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8. SOOP – ENVIRONMENTAL DNA SAMPLER

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Outline

Marine ecosystems provide essential services with global and human relevance such as carbon sequestration, nutrient cycling, or food provision. The biodiversity in marine ecosystems sustains ecosystem functionality and the provision of these ecosystem services. Marine biodiversity is considered an Essential Ocean Variable (EOV) that needs extensive observation to assess potential changes expected in response to environmental change in the marine realm due to anthropogenic climate change (Boss et al., 2018). Over the past two decades, eDNA biodiversity studies have emerged as a valuable tool in ecological studies, also in the marine realm. This kind of analyses enhances our ability to monitor ecosystems and their functionality effectively, while minimizing disturbance of the system and allowing observations across all organismic size classes from the very small marine microbes to large predators. eDNA based biodiversity studies are based on the principle that all organisms in the ecosystem release DNA in the environment, which can be collected for molecular genetic analyses by filtration. The distribution of organisms in the marine realm is very patchy, as it is tightly coupled to environmental conditions and physical forcing. Thus, a comprehensive understanding of marine biodiversity requires approaches that allow capturing marine biodiversity at adequate temporal and spatial scales, considering the high degree of variability in the marine environment. Acknowledging this, establishing eDNA sampling onboard ships of opportunity that provide samples to monitor marine biodiversity is a key task of the SOOP project with the perspective to significantly enhance monitoring of marine biodiversity in the future.

As technology continues to advance, the application of eDNA is likely to expand further, providing deeper insights into marine biodiversity, ecosystem functionality and its conservation based on dedicated process studies, time-series observations and large-scale observations building up on eDNA sampling via ships of opportunity, see Figure 8.1.

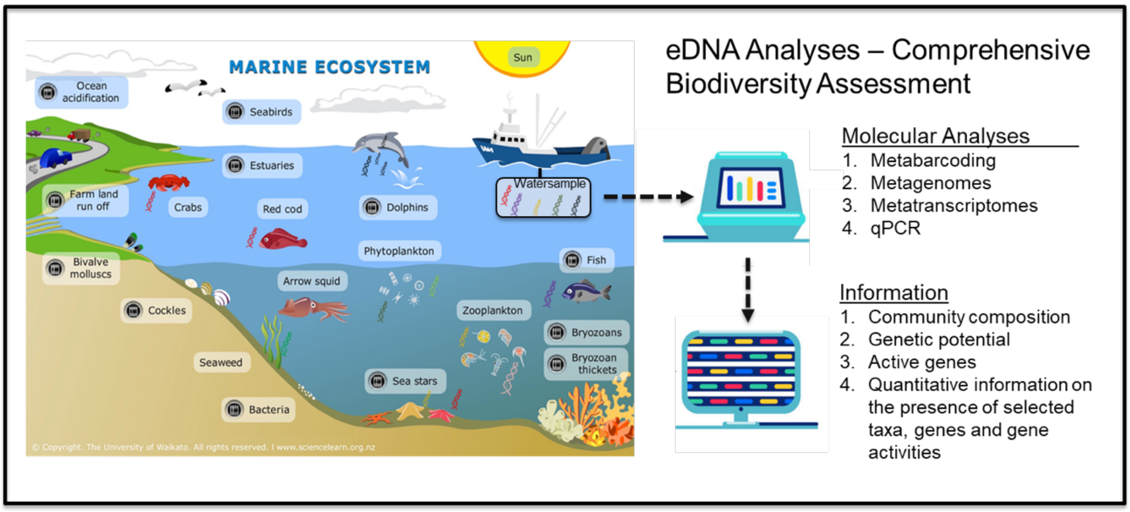

Fig. 8.1: Schematic overview on the potential of eDNA analyses to provide comprehensive system oriented, information on marine biodiversity

Objectives

The eDNA-Sampler used on board the cruise ship MS *Fridtjof Nansen*, the Particle and Phytoplankton Sampler (PPS) is a 24-port filtration sampler, which can sample automatically according to a created deployment schedule for longer time periods. In this project we changed its original use to fit the needs of onboard sampling while being connected to a piping system. Its primary purpose is to filter ocean water and collect DNA which then can be further analyzed in laboratories, providing crucial insights into the living along the cruise tracks. The samples will be analysed in the laboratory with respect to the biodiversity of eukaryotic microbes and will be made available to assess the applicability of eDNA analyses for fish-stock assessment by the Marine and Freshwater Research Institute of Island (Dr. Christophe Pampoulie).

Work at sea

The PPS was operated during the journey around Iceland (Reykjavik – Reykjavik) from 24 May to 1 June 2024. In Figure 8.2 it can be shown the installed PPS (Particle and Phytoplankton Sampler) in the auxiliary engine room (deck 1) as part of the underway system. On a second journey from 2 September – 18 September 2024 along the coast of Alaska up to the Pacific Canadian waters the device was tested for functionality, while samples have not been collected due to the lack of research permit in the US and Canadian Exclusive Economic Zone.

The system was installed also with the other SOOP-instruments inside in the auxiliary engine room (deck 1). The system has to be connected to a laptop to create a deployment schedule and setup the sampling. The system then runs automatically until the 24 filters have to be replaced. The filters have to be exchanged manually and the samples have to be stored for further analysis.

In total, a set of 14 samples (Table 8.1) was collected along the coast of Iceland. This included the filtration of 2 liters of sea water. Subsequent to filtration samples were preserved with ethanol and frozen at -20°C until further processing the laboratory.

Fig 8.2: The PPS (Particle and Phytoplankton Sampler) installed on board of MS Fridtjof Nansen

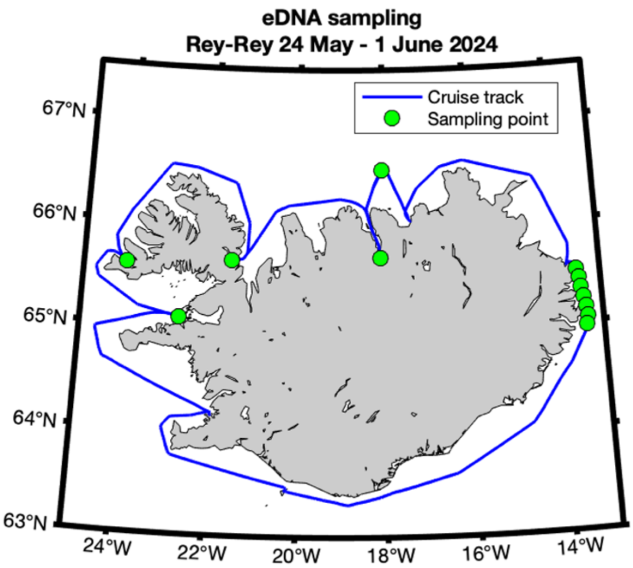

Fig. 8.3: Overview on the sampling during the voyage from 24 May to 1 June 2024 - the first analytical process of the sampling was done on board the MS Fridtjof Nansen

Tab. 8.1: Stations samples with the PPS eDNA sampler during the cruise along the coast of Iceland

	time - UTC (start of filtration)	Station	Latitude [deg]	Longitude [deg]	Filtrated volume [ml]
25/05/2024	16:32:00	Stykkesholmur	65.084414° N	-22.719308° W	700
26/05/2024	14:57:00	Patreksfjordur	65.593000° N	-23.999638° W	1200
27/05/2024	16:05:00	Saudfjarsetur	65.653037° N	-21.570893° W	2000
28/05/2024	16:14:29	Akureyri	65.687942° N	-18.075159° W	2001
28/05/2024	16:36:27	Akureyri	65.687942° N	-18.075160° W	2000
29/05/2024	14:59:17	Grimsey	66.533174° N	-18.021812° W	2001
29/05/2024	15:21:30	Bakkagerdi	66.533268° N	-18.021550° W	2001
30/05/2024	14:37:24	Bakkagerdi	65.505004° N	-13.544731° W	2001
30/05/2024	14:59:55	Bakkagerdi	65.416985° N	-13.506209° W	2001
30/05/2024	15:22:33	Bakkagerdi	65.329481° N	-13.469285° W	2001
30/05/2024	15:45:20	Bakkagerdi	65.236647° N	-13.431590° W	2001
30/05/2024	16:08:14	Bakkagerdi	65.142991° N	-13.385579° W	2001
30/05/2024	16:31:14	Bakkagerdi	65.048878° N	-13.363296° W	2000
30/05/2024	16:51:52	Bakkagerdi	64.965456° N	-13.388809° W	1772

Preliminary (expected) results

The aim of the journey was to test the system connected to a multi-instrument rack with a tubing system and establish an operating routine for this purpose. The main aim is to collect eDNA samples, which can be analyzed later on for the desired target species. In Figure 8.3 you can find an overview on the sampling during the voyage from 24 May to 1 June 2024. The first part of the analytical process from sampling was done on board the MS *Fridtjof Nansen*. The final analysis is planned in the next months in the laboratory at AWI Bremerhaven.

Data management

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). Processed data, including annotated sequence information to allow inferences about the biodiversity in the samples 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 “SOOP – Shaping an Ocean Of Possibilities”, see https://www.soop-platform/earth/en/homepage-2/) one of the innovation platforms, as part of the Helmholtz Innovation Platform programme, funded from the “Pakt für Forschung und Innovation”.

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9. SOOP – ATMOBOX PAMOS

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Outline

Within the SOOP operations onboard we installed a Portable Atmospheric Measuring Box On Sea (PAMOS) for continuous atmospheric measurements. The PAMOS atmospheric measurement box is a sophisticated, mobile measurement system specially developed for the precise recording and analysis of climate variables (Bayer et al., 2024). Its design allows for flexible deployment both at sea and on land, making it ideal for scientific expeditions and research projects in remote or hard-to-reach areas. PAMOS is designed to measure a wide range of atmospheric parameters, filling an important gap in global environmental monitoring. The atmospheric box measures the aerosol particle matter (PM) in different size classes, the aerosol number concentration as well as the black carbon concentration. Furthermore, it observes the trace gases concentrations of CO2, CO, CH4, SO2, and NO2 as well as the meteorological parameters, like temperature, humidity, wind speed and wind direction, air pressure and precipitation will be measured. The instruments are part of the oceanic and atmospheric measuring strategy of SOOP on board of the MS *Fritdjof Nansen*.

Objectives

The PAMOS (Portable Atmospheric Measuring Box On Sea) represents a significant step towards the collection of atmospheric data on the world's oceans, which is crucial for understanding the global climate. Designed for use on mobile platforms such as ships, PAMOS enables precise observations of ECVs (Essential Climate Variables) in environments that are difficult to access. The primary purpose is to bridge the gap in observational data over the oceans, providing crucial insights into climate patterns. The collection of such data is not only essential for basic research, but also for the development of strategies to tackle climate change. The more accurate and comprehensive the data collected, the more precise the climate models and forecasts can be. PAMOS makes a valuable contribution to the monitoring and understanding of our environment by providing highly relevant data from locations that could previously only be insufficiently observed. Shipping contributes a not inconsiderable 15% to the global temperature increase through CO_2 emissions. A significant increase in shipping traffic is expected, along with a further increase of the temperature. Limiting the global temperature increase to 1.5° C (https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/_paris_abkommen_bf.pdf) is difficult to comply with. Measuring aerosol and trace gas concentrations in the oceans is an essential prerequisite for the development of action strategies to limit the temperature increase caused by human activities. The provision of adequate sensor technology and measurement platforms to record the relevant parameters is necessary as part of the climate debate and environmental protection. By combining these diverse measurements, PAMOS provides a detailed insight into the atmosphere and its interactions with the oceans, making it a valuable tool for society and research worldwide.

Work at sea, including the description of the measurements

During the voyage along the west coast of Greenland from Qaqortoq to Ilulissat and back with the expedition ship MS *Fridtjof Nansen*, the PAMOS system was successfully tested. The PAMOS was operated during one voyage from from Reykjavik to Reykjavik via along the Greenland coast up tp Ilulissat (28 July – 8 August 2024). The system was installed on deck 10, on top of the bridge (Figure 9.1). After the installation of the system, we carried out measurements of different atmospheric parameters. The aim was to check the operational status of the system and the automatization procedure switching on and off the measurements depending on the weather conditions. The system is particularly suitable for use on mobile platforms such as expedition ships, ferries and container ships, but also on research vessels, where it can collect and process data in real time. This mobility makes it possible to carry out critical measurements even in remote ocean regions that are traditionally undersampled. Due to its robust design, PAMOS is able to operate reliably in a wide range of environmental conditions, making it an indispensable tool in climate research.

Fig. 9.1: The PAMOS system, installed on board of the MS Fridtjof Nansen

Preliminary (expected) results

During the journey from 28 July to 8 August 2024 one of the aims was to test the system and finally switch into operational mode. The main aim was to collect atmospheric parameters over the ocean. The system will contribute to the collection of valuable data, which is of great importance both for the scientific community and for the further development of climate research. These measurements close a crucial gap in the available observational data over the oceans, as they provide information on aerosol and soot particles, selected trace gases such as CO2 and methane, as well as relevant meteorological parameters. In Figure 9.2 selected meteorological parameter, like air temperature (left hand side) and relative humidity (right hand side) are shown. On the other hand, the Figure 9.3 represents the variability of the aerosol concentration (particle number concentration and the Black Carbon concentration) along the coast of Greenland. All these data are preliminary.

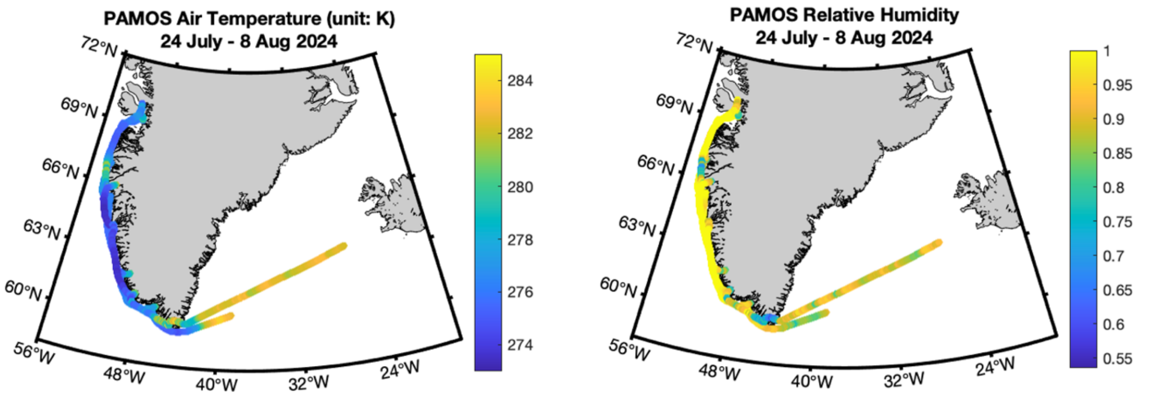

Fig. 9.2: Measurements of the meteorological parameters: temperature (left) and relative humidity (right) for the time period from 28 July to 8. August 2024

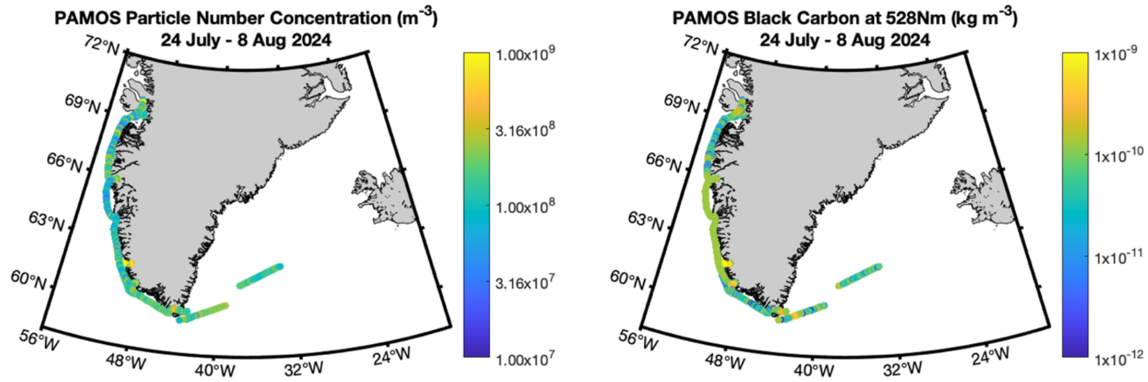

Fig. 9.3: Measurements of the aerosol parameters: particle number concentration (left) and Black Carbon concentration (right) for the time period from 28 July to 8. August 2024

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 4.0 license will be applied.

This expedition was supported by the Helmholtz Research Programme "SOOP – Shaping an Ocean Of Possibilities", see https://www.soop-platform/earth/en/homepage-2/) one of the innovation platforms, as part of the Helmholtz Innovation Platform programme, funded from the "Pakt für Forschung und Innovation".

References

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APPENDIX

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

A.3 SCHIFFSBESATZUNG / SHIP‘S CREW

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

Affiliation	Address
On board / In the field	
DE.AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
DE.GEOMAR	GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel Wischhofstrasse 1-3 24148 Kiel Germany
DE.Hereon	Helmholtz-Zentrum Hereon GmbH Max-Planck-Straße 1 21502 Geesthacht Germany
Not on board / Not in the field for scientific operation	
UK.HX	HX	Hurtigruten Expeditions 210 Pentonville Rd N1 9JY, London United Kingdom

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

Name/ Last name	**Vorname/ First name**	**Institut/ Institute**	**Beruf/ Profession**	**Fachrichtung/ Discipline**
Dutzi	Myriam	DE.GEOMAR	Scientist	Public Outreach
Herber	Andreas	DE.AWI	Scientist	Physics
Hildebrand	Lars	DE.Hereon	Scientiost	Chemistry
Köhler	Laura	DE.AWI	Scientist	Physics
Mai	Julian	DE.AWI	Engineer	Engineering Science
Paulsen	Melf	DE.GEOMAR	Engineer	Engineering Science
Rohrweber	Ann-Cathrin	DE.Hereon	PhD student	Chemistry
Steinhoff	Tobias	DE.GEOMAR	Scientist	Oceanography
Xi	Hongyan	DE.AWI	Scientist	Biology

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

Ship's crew of the MS *Fridjof Nansen* for the voyages from FNICE2412 up to FNGRE2016	
Cruise leg / Name	**Position / Rank**
FNICE2412 (Circumnavigating Iceland)	
Raymond Martinsen	Master
Trond Lippestad	Chief Officier
Jan Robin Pettersen	Chief Engineer
Friederike Bauer	Expedition Leader
Guila Bellon	Science & Education Coordinator
FNICE2413 (Circumnavigating Iceland)	
Bent Ivar Gangdal	Master
Trond Lippestad	Chief Officier
Jan Robin Pettersen	Chief Engineer
Leoni Dickerhoff	Expedition Leader
Tim Lardionis	Science & Education Coordinator
FNICE2414 (Circumnavigating Iceland)	
Bent Ivar Gangdal	Master
Trond Lippestad	Chief Officier
Jan Robin Pettersen	Chief Engineer
Tessa van Drie	Expedition Leader
Guila Bellon	Science & Education Coordinator
FNICE2415 (Reykjavik – Greenland – Reykjavik)	
Bent Ivar Gangdahl	Master
Bram Olaf van Spiel	Chief Officier
Jan Robin Pettersen	Chief Engineer
Tessa van Drie	Expedition Leader
Tim Lardionis	Science & Education Coordinator
FNICE2416 (Reykjavik – Greenland – Reykjavik)	
Raymond Martinsen	Master
Trond Lippestad	Chief Officier
Jan Robin Pettersen	Chief Engineer
Friederike Bauer	Expedition Leader
Guila Bellon	Science & Education Coordinator

Ship's crew of the MS *Fridjof Nansen* for the voyages from FNGRE2417 up to FNNWP2420	
Cruise leg / Name	**Position**
FNICE2417 (Reykjavik – Greenland – Reykjavik)	
Bent Ivar Gangdal	Master
Trond Lippestad	Chief Officier
Jan Robin Pettersen	Chief Engineer
Leoni Dickerhoff	Expedition Leader
Tim Lardionis	Science & Education Coordinator
FNICE2418 (Reykjavik – Greenland – Reykjavik)	
Bent Ivar Gangdal	Master
Bram Olaf van Spiel	Chief Officier
Jan Robin Pettersen	Chief Engineer
Friederike Bauer	Expedition Leader
Sophie van der Hart	Science & Education Coordinator
FNNWP2419 (Northwest Passage)	
Bent Ivar Gangdahl	Master
Bram Olaf van Spiel	Chief Officier
Jogvan Olsen	Chief Engineer
Friederike Bauer	Expedition Leader
Tim Lardionis	Science & Education Coordinator
FNNWP2420 (Alaska – British Columbia)	
Raymond Martinsen	Master
Trond Lippestad	Chief Officier
Jogvan Olsen	Chief Engineer
Friederike Bauer	Expedition Leader
Tim Lardionis	Science & Education Coordinator

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