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Reports on Polar and Marine Research

The Expedition PS132 of the Research Vessel Polarstern to the Atlantic Ocean in 2022

Edited by

Karen H. Wiltshire and Angelika Dummermuth

with contributions of the participants

HELMHOLTZ

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Titel: Expeditionsteilnehmer des North South Atlantic Training 2022 (OCEANCAPX | NoSoAT) auf dem Monkey Island der Polarstern (Foto: Angelika Dummermuth, AWI)

Cover: Participants of the North South Atlantic Training 2022 (OCEANCAPX | NoSoAT) on Monkey Island of Polarstern (Photo: Angelika Dummermuth, AWI)

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PS132

30 August 2022 – 29 September 2022

Bremerhaven – Cape Town

Chief scientist
Karen H. Wiltshire

Coordinator
Ingo Schewe

Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Karen Wiltshire, Angelika Dummermuth DE.AWI

Die Transitfahrt PS132 der *Polarstern* startete am 30.09.2022 in Bremerhaven und endete am 29.09.2022 in Kapstadt. Die Fahrt stand im Zeichnen der studentischen Ausbildung. Eine internationale Gruppe von 13 Studierenden aus 13 Ländern wurde während dieses Trainingsprogramms in Wissen und Techniken der Ozeanographie und der Mikrobiologie geschult. Dabei lernten sie Methoden der Probennahme, der Aufarbeitung der Proben und den Umgang mit erhobenen Daten. Vor Fahrtbeginn fand ein 5-tägiger Workshop aller Teilnehmenden zur Vorbereitung auf die Fahrt statt.

Als weitere Aufgabe während der Transitfahrt wurden chemische und physikalische Messungen zum Energie- und Massenaustausch zwischen Ozean und Atmosphäre durchgeführt. Zudem bekamen die Studierenden eine Einführung in die Physik des Klimasystems, internationale Klimaverhandlungen und die Ziele der UN Ozeandekade. Auf dem sogenannten Nord-Süd-Atlantik-Training-Transekt erhielten sie Einblicke in die Meereswissenschaften und führten Kurzprojekte zu den Wechselwirkungen zwischen Ozean, Atmosphäre und Klima durch. Die Stipendiaten lernten die Vermittlung von Wissen praktisch an Bord u.a. durch Gestaltung des Instagram Accounts des NF-POGO Centre of Excellence for Observational Oceanography und des Miniboot-Projekts im Rahmen von Educational Passages. Schülerinnen und Schüler aus Irland, Spanien, Südafrika und Deutschland hatten kleine Boote zusammengebaut, die mit GPS und Temperatursensoren ausgestattet waren und die von *Polarstern* ausgebracht wurden. Über Videoverbindung wurde den Schülerinnen und Schülern die Vorbereitung und das Ausbringen der Miniboote präsentiert, über die Rolle des Ozeans im Klima diskutiert. Die Eindrücke von der Fahrt und das Bewusstsein für das Meer und den Klimawandel wurden somit direkt ins Klassenzimmer getragen. Eine weitere Gelegenheit live von Bord zu berichten, war die Beteiligung an den Sylter Nachhaltigkeitstagen mit einem Vortrag der Professoren Lemke und Wiltshire.

Das Trainingsprogramm war ein gemeinsames Projekt zwischen dem Alfred-Wegener-Institut, dem Max-Planck-Institut für Marine Mikrobiologie in Bremen (MPI Bremen), Partnership for Observation of the Global Oceans (POGO) und mit Unterstützung von Educational Passages. Die Sommerschule wurde durch die Nippon Foundation / POGO Centre of Excellence finanziert und von REKLIM (Helmholtz Verbund Regionale Klimaveränderung) unterstützt. Sie ist als Aktivität der UN Ocean Decade gelistet.

Am 29.09.2022 lief *Polarstern* in Kapstadt ein und damit endete die Expedition PS132.

SUMMARY AND ITINERARY

The transit cruise PS132 of *Polarstern* started on 30.09.2022 in Bremerhaven and ended on 29.09.2022 in Cape Town. The cruise was dedicated to the training of NIPPON-POGO scholarship scholars. Prior to the shipboard training a five-day land-based workshop was held to prepare the scholars in application and usage of programming tools and methods while in quarantine. An international group of 13 scholars from 13 nations has been trained in oceanographic techniques, microbiology and ocean knowledge during this shipboard training. The scholars learned methods of data collection, processing and handling. The participants learned how to take samples, how to process them and deal with the accompanying data. The main water masses between the North Sea and the Atlantic were characterized in terms of their hydrographic features down to a depth of approx. 500 m and more.

As an additional task during the transit, chemical and physical measurements of the energy and mass exchange between ocean and atmosphere have been performed. Furthermore, the students got an introduction to the physics of the climate system, and the goals of the UN Ocean Decade. On the North South Atlantic Transect the scholars got insights in marine sciences and conducted individual projects on the interactions between ocean, atmosphere and climate. They learned how to translate knowledge in practice on board for example by feeding the Instagram account of the NF-POGO Centre of Excellence for Observational Oceanography as well as of the miniboat project in the frame of Educational Passages. Pupils from Ireland, Spain, South Africa and Germany assembled little boats equipped with GPS and temperature sensors which have been deployed from *Polarstern* by scholars. Per videoconference they presented the preparation and the deployment to the pupils and discussed the role of the oceans with them. Experiences from the cruise and awareness on the ocean and climate change could be transported directly to the class rooms. The sustainability days on Sylt were a good opportunity to report live from board and contribute with a presentation by Professors Lemke and Wilshire.

The training programme was a joint project between the Alfred Wegener Institute, the Max Planck Institute for Marine Microbiology in Bremen (MPI Bremen), the Partnership for Observation of the Global Oceans (POGO) and Educational Passages. The summer school was funded by the Nippon Foundation / POGO Centre of Excellence and supported by REKLIM (Helmholtz Network on Regional Climate Change and Humans). It is listed as an activity of the UN Ocean Decade.

The *Polarstern* arrived in Cape Town on 29 September 2022 and the expedition PS132 ended.

WEATHER CONDITIONS DURING PS132

Christian Rohleder DE.DWD

The transit cruise PS132 from Bremerhaven to Cape Town - called NoSoAT (North-South-Atlantic-Transect) – was used for chemical and physical measurements of the energy and mass exchange between ocean and atmosphere. In the process, an international group of 14 students was trained in the knowledge and techniques of oceanography.

Bremerhaven - Rotterdam

On 30.08.2022 at about 14 UTC, expedition PS132 started in Bremerhaven. The first destination was Rotterdam, where a short stop was made to bunker fuel. A high-pressure system centred on the Norwegian Sea and an associated wedge extending across Denmark to the Czech Republic caused an easterly to north-easterly current over *Polarstern*'*s* cruising area in the southern North Sea. During the first hours of the voyage along the Dutch coast, wind speeds of around 5 Bft were recorded. Only during the course of the second day of the voyage did the wind freshen further, reaching 6 Bft shortly before Rotterdam with gusts of up to 7 Bft and significant wave heights of almost two metres. *Polarstern* reached the bunker pier after a two-hour channel navigation on the Rhine on 31 August 2022 at around 18 UTC.

Rotterdam - English Channel - Bay of Biscay

On 01 September 2022 at about 10 UTC, refuelling was completed, *Polarstern* left the bunker pier and reached the open sea off Rotterdam after about two hours. During *Polarstern*'s stay in the harbour, the wedge emanating from the high-pressure zone over northern Europe swung north-eastwards, weakening. In its fringes, the wind blew from easterly directions at 5 Bft, and the significant wave height was about 1.5 metres. Upon reaching the English Channel, the wind and swell decreased noticeably. A weak low-pressure system (1013 hPa) over the Bay of Biscay, which moved northwards over the English Channel on 02 September 2022, brought weak to moderate winds during the passage through the Channel, which shifted from east to northwest to west in the course of the day.

At the same time, a depression moved southwest of Iceland, deepening to the south. On 03 September 2022 it reached the sea area west of Ireland. An associated extension crossed the sailing area of *Polarstern* in the course of the same day, bringing moderate rain and wind speeds of up to 7 Bft, in gusts up to 8 Bft. The significant wave height in this section was approx. 2 metres.

In the course of the following night, another low-pressure system developed on the edge of the central low to the west of Ireland, which moved south-eastwards and developed into a storm low, the core of which reached the sea area southwest of Ireland in the course of 4 September 2022. As this development was already apparent during *Polarstern*'s passage through the English Channel, the usual cruising speed of 10.5 Kt was increased to more than 12 Kt. As a result, the ship reached a position west of Cape Finisterre in the late afternoon of 04 September 2022 and was thus able to largely avoid meeting the storm low. Nevertheless, the mostly south-westerly wind increased to 8 Bft during the day and even reached 9 Bft in short gusts, building up a sea with average wave heights of more than three metres. During the following night, *Polarstern* moved further and further away from the direct influence of the storm low on its way south, the wind decreased to less than 6 Bft.

West of Portugal - Canary Islands

As *Polarstern* continued southwards, the low-pressure system weakened slightly and moved across the British Isles and the English Channel to the Netherlands. The Azores High (1,023 hPa), centred northwest of the Canary Islands, and a wedge extending from it to Portugal became weather-dominating for the sailing area. The last light rain showers were observed in the night of 05 September 2022. The sea state levelled off at around two metres by 06 September 2022, the wind blowing from westerly, later north-westerly directions weakened to 3-4 Bft.

When it reached the area around the Canary Islands on 08 September 2022, the core of the Azores High lay to the west of *Polarstern* and its wedge extended to Gibraltar. South of the high, already in the area of the tropical depression trough, smaller low-pressure areas moved eastwards from Mauritania and Senegal. This resulted in a fresh to strong north-easterly current in the area. This was significantly strengthened by orographic effects during the voyage between the Canary Islands. In the night of 09 September 2022 – *Polarstern* passed the 3,715 m high Teide on Tenerife – wind speeds of up to 8 Bft from north-easterly directions were recorded. The significant wave height was always in the range of 2 to 2.5 m from north-westerly to northerly directions during the voyage to the south of the Canary Islands.

Cape Verde Islands - Inner Tropical Convergence Zone - Equator

Due to intense low-pressure activity in the North Atlantic, the Azores High shifted south-westward until 11 September 2022 near N30 W035. *Polarstern* moved along its south-eastern flank in a mostly fresh, sometimes strong northerly to north-easterly trade wind.

While *Polarstern* passed the Cape Verde Islands to the east on 11/12 September 2022, a depression embedded in the tropical low-pressure zone off the coast of Senegal moved westwards over the area. On its north-western flank, the wind continued to blow from northerly directions with 4-5 Bft. In the afternoon of 12 September 2022, isolated thunderstorms and moderate, partly heavy rain showers were observed over the ship. Occasionally the wind freshened up to gusts of 7 Bft.

On 13 September 2022 the low was south of Cape Verde and *Polarstern* was on its southeast flank. The wind was now blowing from a south-westerly direction with 5 Bft. The passage of the low had little influence on the significant wave height, which, apart from brief increases due to an elevated wind sea during the showers and thunderstorms, was fairly constant at around 2 metres.

While *Polarstern* left the area of the inner-tropical convergence zone to the south until 16 September 2022, further, mostly small-scale lows moved westwards from the coast of Senegal and again brought showers and thunderstorms, the focus of which, however, was now north of the area of the cruise. The last shower was observed on 15 September 2022, at which time the ship was at about 05N.

By the time the ship reached the equator in the night of 17 September 2022, the weather had calmed down considerably, the wind shifted to southerly to south-easterly directions and reached 4-5 Bft. In addition to the main swell from westerly directions, a second swell from southerly directions was observed, which manifested itself as the main swell when the ship passed the equator.

Southeast Atlantic to Cape Town

After passing the equator, *Polarstern* initially moved in a weak southerly to south-easterly flow in an area of low air pressure gradient. A high-pressure system (1036 hPa) with its centre near 40S 20W shifted eastwards, weakening slightly, and reached the west coast of South Africa by 20 September 2022. In conjunction with an opposing low-pressure zone over the African continent, this finally caused an increased pressure gradient off the Namibian coast. However, *Polarstern* only reached this area in the course of 23 September 2022 and remained in south-easterly winds with 4-5 Bft in trade wind conditions typical for this region. The swell in this part of the journey was 2 metres from southerly directions.

In the further course, the high slowly moved further eastwards. Another high followed, centred at 45S 18W, with a northward moving wedge. On its eastern flank, supported by a high-altitude trough, an independent low with a core near 35S 03E was able to develop on 23 September 2022. This low slowly moved southwards until 28 September 2022, weakening and disturbing the otherwise prevailing trade winds. *Polarstern* approached this low on its northeast flank on its way towards Cape Town. Therefore, the wind slowly shifted to westerly directions until 27 September 2022 and weakened more and more. In the night of 28 September 2022, there were finally circulating weak winds with a swell of just under two metres from south-westerly directions.

In the course of the last day of the voyage, the subtropical high was located at 40S 36E and a wedge extended into the sailing area of the *Polarstern* shortly before Cape Town. During this day, an independent high developed in this wedge in the sea area west of South Africa. As a result, the pressure gradient intensified somewhat and there was a brief increase in the wind to 5-6 Bft from southerly directions during the night before *Polarstern* arrived in Cape Town.

In the morning hours of 29 September 2022 *Polarstern* finally reached the port of Cape Town under cloudy skies and lightly circulating winds

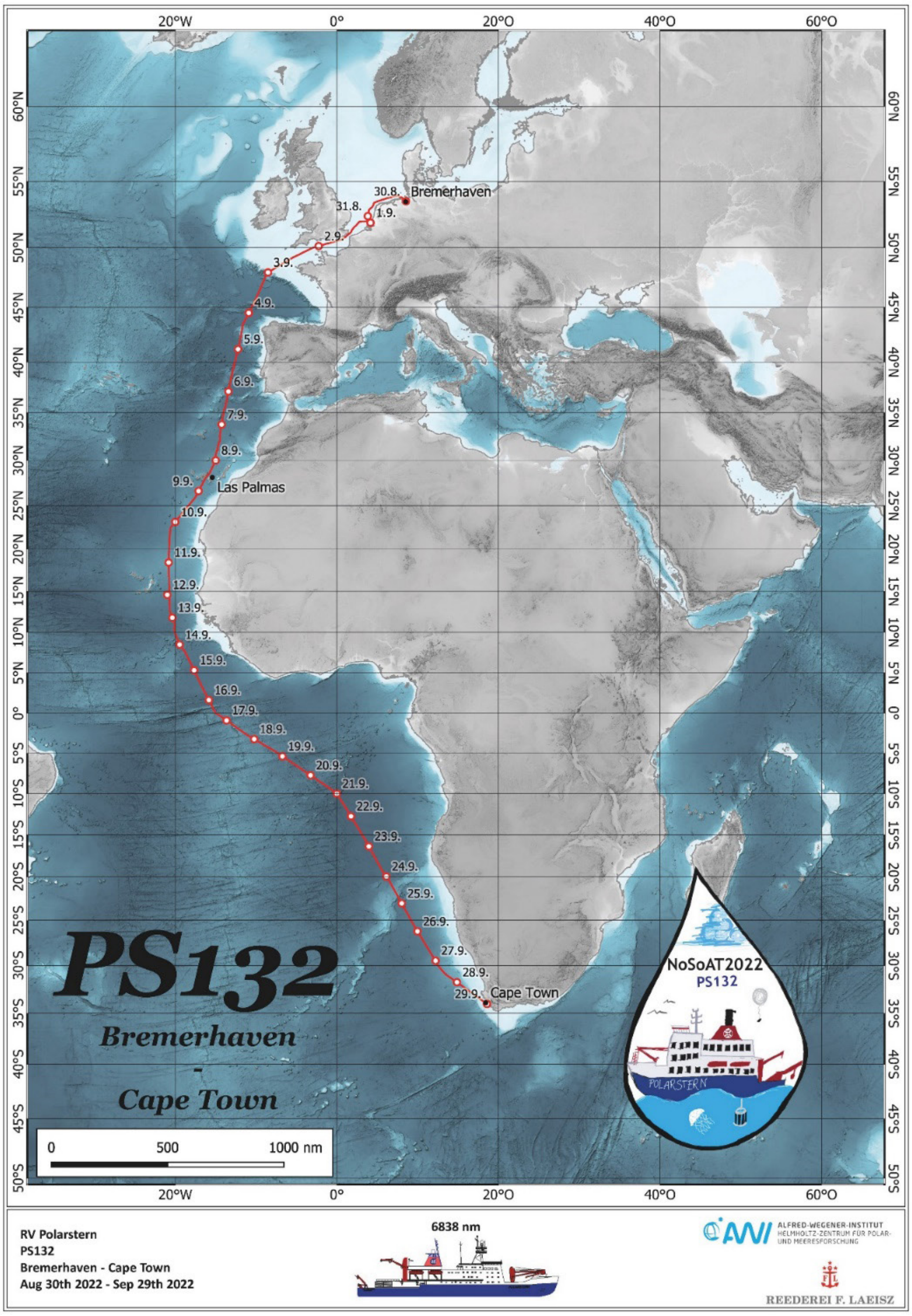

Abb. 1.1: Fahrtroute von Bremerhaven nach Kapstadt (Karte von Frederic Tardeck); siehe https://doi.pangaea.de/10.1594/PANGAEA.952489 für eine Darstellung des master tracks in Verbindung mit der Stationsliste für PS132

Fig. 1.1: Cruise track from Bremerhaven to Cape Town (map by Frederic Tardeck); see https://doi.pangaea.de/10.1594/PANGAEA.952489 to display the master track in conjunction with the station list for PS132

2. NORTH SOUTH ATLANTIC TRAINING 2022 (OCEANCAPX | NOSOAT)

Karen Wiltshire[1], Peter Lemke[1], Eva-Maria Brodte[1] (not on board), Angelika Dummermuth[1], Maïté Guignard[1], Vera Fofonova[1], Dmitry Sidorenko[1], Rudolf Amann[2], Peter Croot[3]; Alex Baker[4]

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Grant-No. AWI_PS132_01

Outline

In the framework of the UN Ocean Decade – The Science We Need for the Ocean We Want (https://www.oceandecade.org/) these educational and outreach activities trained young scientist in hands-on oceanographic methods and practical knowledge by an international team of teachers. During this expedition, these early career professionals in marine science had been connected globally with a wider audience including pupils.

Objectives

Aim of the training programme NoSoAT was to identify and characterize different water bodies along a North-South Atlantic transect, as part of training exercise for capacity building in oceanography. An international group of 13 students (mostly graduate level and doctoral candidates) was trained in basic oceanographic principles including seagoing methods and sampling associated with these, as well as bacterial and phytoplankton communities in water samples. The expedition track led via cross coastal, shelf and open Atlantic Ocean waters. Specifically, participants learned how to sample and analyze the ocean properties as "Ground Truth" information for Remote Sensing information and how to communicate scientific results to the general public and school kids. The survey participants were divided into groups of two or three, which rotated between the five main disciplines, which were Climate System, Oceanography, Modelling, Climate, Bathymetry and Microbiology (Fig. 2.1).

Objectives of the floating summer school included:

- Differentiation of different water masses via temperature, salinity, turbidity etc.
- Localization of thermocline
- Detection of salinity gradients and turbidity
- Comparison of ground-truth data with remote sensing
- Measurements of atmospheric properties
- Studies of climate physics
- Discussion of the law of the sea and its impacts on in-situ marine observations

Additionally, the scholars were trained in outreach projects as blog writing, conducting short video footages for education purposes, answering questions from school kids via skype etc.

Each group rotation lasted 4-5 days and included an average of two stations per rotation. At the end of each rotation, students had a project day set aside to work on preparing that evenings presentation and on individual projects and the hand over to the following group.

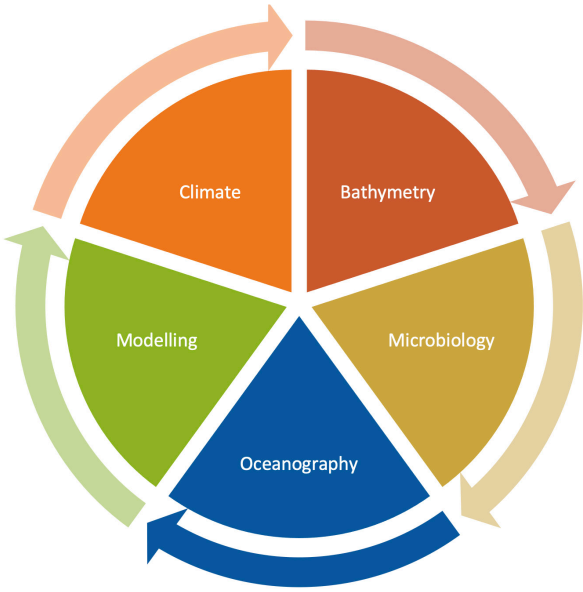


Fig.2.1: Rotation scheme of the scholars modules during the PS132 expedition

Oceanography

In the oceanography module the scholars were introduced to different sampling concepts, sampling planning, sampling techniques, sampling devices, measurement techniques and accuracy, and common oceanographic instrumentation. The gears the scholars were trained in were CTD sensor packages and rosette, expendable Bathythermographs (xBTs) and Thermosalinograph/Ferrybox Underway measurements. A specific research interest is to quantify the ocean heat content (OHC) and is therefore an important tool to be trained on.

Marine phytoplankton organisms are the main primary producers in our oceans. The essential role of phytoplankton and their value as a highly sensitive ecological indicator makes their study a key approach for evaluation of the status and changes of marine ecosystems, as well as to understand its influence in the pace of climate change. During the previous NoSoAT and SoNoAT expeditions, information on phytoplankton was collected through distinct approaches, including both discrete and continuous sampling. The specific objectives of the phytoplankton submodule on PS120 were to

- Collect a high spatial and temporal resolved data set on phytoplankton (total and composition) at the subsurface using continuous optical measurements along the cruise transect;
- Develop and validate (global and regional) remote sensing algorithms in accordance with the previous objective by using discrete water samples for pigment analysis;
- Collect discrete samples for taxa identification through detected morphological features via microscopy;
- Identify bio-physical-chemical coupling by using comprehensive data sets to detect shifts in phytoplankton community biomass and composition and the factors driving the variability and changes in the phytoplankton community.

Microbiology

Understanding bacterial communities is necessary to understand the environment in which they appear. The unicellular organisms are key degraders of biomass and polysaccharides and drive nutrient fluxes, especially with regard to the carbon cycle (Nagata, 2018). They effect all trophic levels and are bound to react to changes in temperature, pH, oxygen concentration and other abiotic factors (Boetius, 2019). Microbial community determination across the Atlantic has been done before (Agogué et al., 2011), but the generally small percentage of well described (=cultured) strains and infrequent sampling across these transects leaves many uncertainties. Unique sampling cannot show changes in a system, so in order to recognize shifts a repeated analysis with state-of-the-art techniques is required to put the current state into perspective. We compared our results with previous ones and link this information with environmental data (oxygen concentration, temperature, pH, Chl *a* concentration). These abiotic parameters were used to design appropriate cultivation media that resemble the original water body. Cultivability is known to be low for all bacteria (0.1-1%, Ferguson et al., 1984). We aimed to collect and freeze stocks to reactivate them at original growth conditions to cultivate new abundant strains. Once in culture these strains could be used for genome sequencing, proteomics, and physiology analysis, opening the door to a better understanding of the Atlantic bacterioplankton and how they are changing in a changing ocean system.

In the five-day teaching module for each group four topics of microbial ecology were covered (see below). On each day, there were morning lectures. The students subsequently applied the knowledge gained during the instructions in the laboratory. They investigated heterotrophic bacteria in water samples taken along the North-South transect of PS132.

Samples were collected for MSc thesisand furthermore, samples were taken to support the Emmy-Noether-Group of Dr. Greta Reintjes (Department of Molecular Ecology / University of Bremen in March). Fixed virus samples from a few surface water samples were collected. One live deep-water sample from international waters was transferred to Prof. Dr. Rossello-Mora, CSIC-IMEDEA, Spain, in the context of a long-term collaboration. Additional water samples and particle filters from various depths of international waters were taken for bioarchiving purposes at the Max-Planck Institute for Marine Microbiology, Bremen, Germany.

xBT and ADCP measurements

During the PS132 cruise, the temperature profiles were obtained using Expendable Bathythermograph (xBT) probes and velocity profiles were obtained using Acoustic Doppler Current Profiler (ADCP) Teledyne RDI deployed on *Polarstern*. These data were analyzed and compared with the reanalysis data (World Ocean Atlas 2018) and results of the FESOM (global sea-ice ocean model developed at the AWI) simulations during the Ocean Modelling course.

Aerosol sampling

Trace elements, such as iron, are often scarce in surface waters of the ocean and in some cases their availability limits rates of phytoplankton growth or nitrogen fixation. The atmospheric transport of these trace elements to the remote ocean in desert dust therefore plays an important role in regulating the primary productivity of the oceans. Dust transport is highly variable in both space and time, and it is almost impossible to make direct measurements of dust deposition to the ocean. It is therefore difficult to assess the impact of dust deposition, and the micronutrients deposited with it, on ocean biogeochemistry. The ThorMap project aims to make improved estimates of the supply of biogeochemically important trace elements to the ocean via the deposition of desert dust.

The project will make use of dissolved thorium (Th) as a tracer of dust deposition to the surface ocean. The isotope 232Th occurs in surface waters primarily through dissolution from deposited dust. A second isotope, 230Th, is produced in seawater by radioactive decay of uranium (234U). By measuring both of these isotopes, it is possible to accurately determine the amount of dust deposited to the waters at a given location. The proportion of the total amount of Th in dust that will dissolve is also an important parameter in these calculations, but this value is currently not very well known. The project therefore also aims to study the properties of atmospherically transported dust, in order to better constrain the soluble fraction of Th in dust and also the relationships between Th dissolution and the dissolution of the micronutrient trace elements.

Work at sea

CTD Rosette Sampling

Several hours prior to arriving on station, students were introduced to the basics of CTD operation on the *Polarstern*. They learned how to identify the different sensors on the CTD rosette and how to set and check a Niskin bottle prior to deployment. Scholars were taught how to plan their bottle sampling strategy on the upcast, prior to deployment, based on the expected locations of the different water masses anticipated to be encountered at that location. All deck and winch room operations during deployment were explained to the students prior to beginning the station and they were taught the basic operations of the Seabird CTD software, the event logger on the *Polarstern* and the AWI's Manage CTD programme for post processing of the data into ODV. Students took water samples for dissolved gases, nutrients and phytoplankton from the Niskin bottles for use in other sections of this module. At the completion of the station the students cleaned the CTD and prepared the Niskins bottle set in anticipation of the next deployment.

xBT deployment and data retrieval

A resistance in the head of the probe and a very thin twin-wire, connecting the probe to the equipment on the ship, compose the electronic circuit for measuring the water temperature. The probe is designed to fall at a known rate, so that the depth of the temperature profile can be inferred from the time since it enters the water. Deployments were made using a manual launcher, the positions of the XBT stations are identified in Figure 2.2.

Students learned how to setup for an XBT deployment from a moving ship, including communicating with the ship's crew for a safe and successful release of the XBT probe. The students learned how to download the data and to load it into oceanographic software such as ODV. The xBT probe was launched regularly every second day en-route.

ADCP

The operation frequency of the ADCP is 150 kHz. The transducer reaches water depths up to 350 m with a resolution of 4 m and accuracy of about 0.30 m/s for a Single-Ping measurement. The angle between the ship centreline and transducer centreline is 45° direction starboard. The measurements were analyzed for the periods of the CTD stations (Fig. 2.2).

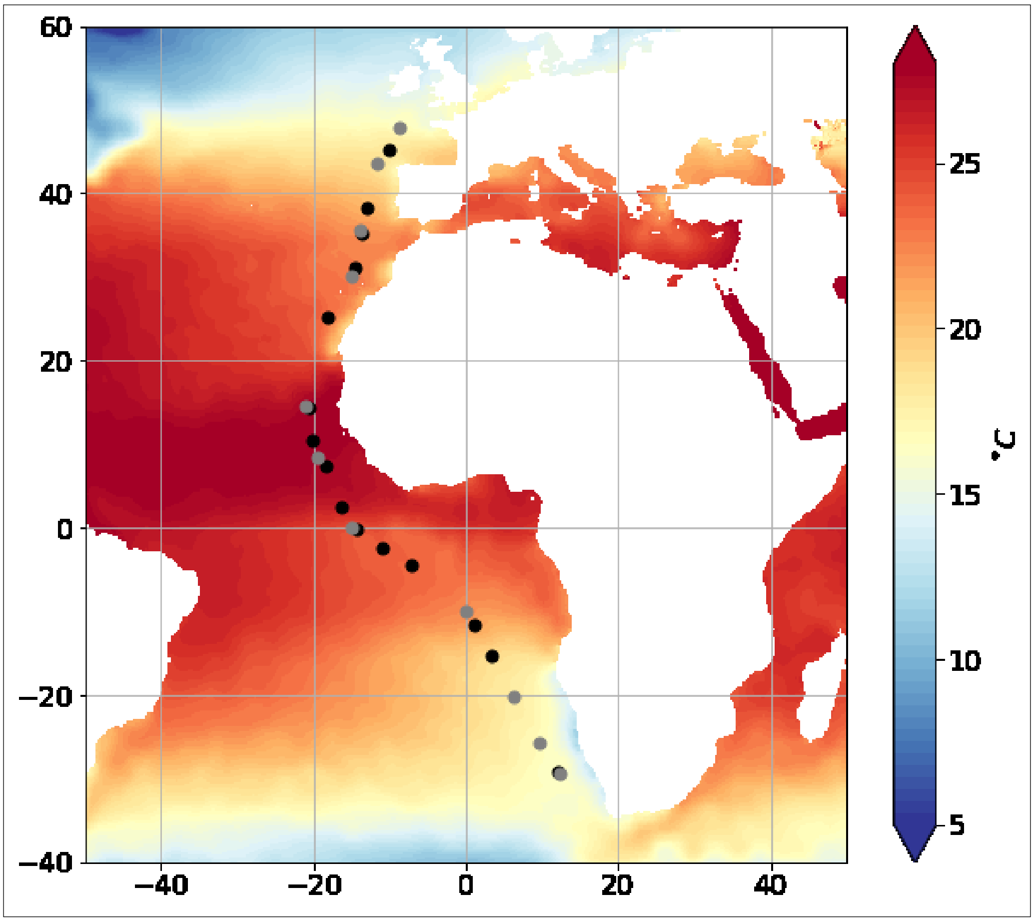


Fig. 2.2: The position of xBT (black dots) and CTD (grey dots) measurements superimposed of mean sea surface temperature for September from World Ocean Atlas 2018

FESOM run

In frame of Ocean Modelling course, we ran FESOM on NG5 mesh, which builds on our previous efforts and experience of creating globally eddy-resolving computational meshes (Fig. 2.3). The size of the mesh is 7.5M surface points, which is close to the size of the conventional 1/12-degree ocean grid. The resolution, however, was distributed in a way that brings more degrees of freedom to energetically active ocean areas, and allows explicit simulation of mesoscale dynamics over most of the global ocean (except parts of polar and coastal areas). The lowest 10-13 km resolution over most of the equatorial regions allows to effectively resolve equatorial processes, and the highest 4 km resolution allowed to resolve mesoscales in the extratropics and in particular is instrumental for simulation of sea ice linear kinematic features. In the vertical, the ocean is discretized by 70 unevenly spaced levels.

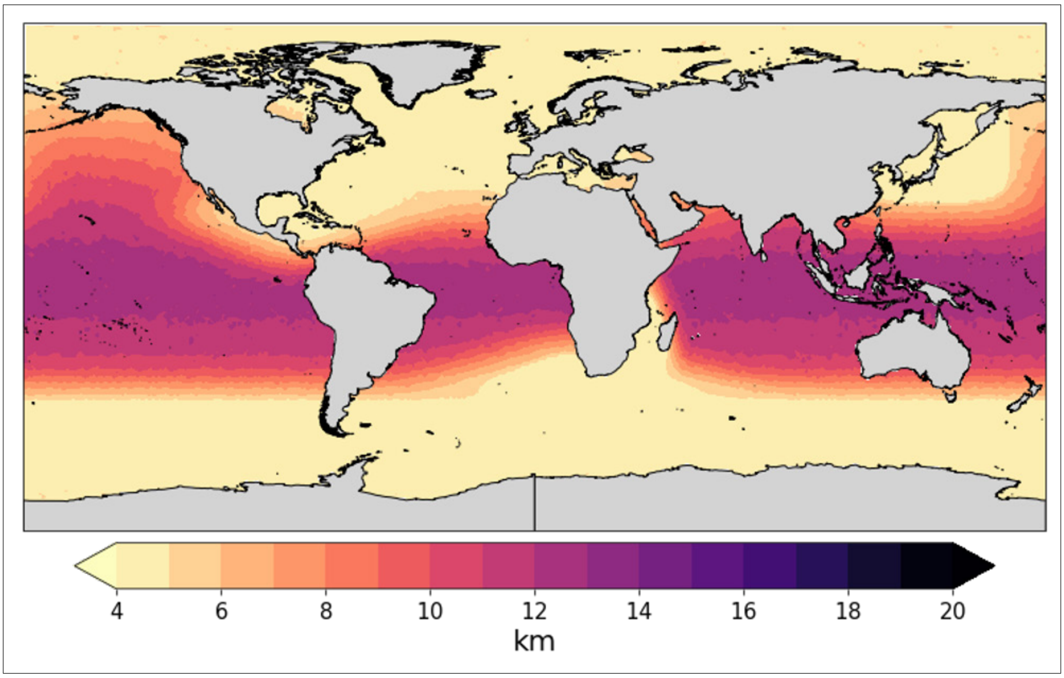


Fig. 2.3: Spatial resolution of NG5 computational mesh for FESOM2; taken from www.fesom.de

FESOM has been run for the years 2009 to 2019 forced by ERA5 atmospheric forcing. The initial condition has been taken from PHC 3.0 climatology. The timestep is 6 minutes.

Water mass identification

Students were introduced to the basics of water mass identification using temperature, salinity and oxygen for the main water masses found along the expedition track. Salinity measurements for CTD calibration were made onboard.

Bacterioplankton sampling

Except for a few bucket samples in the early stage of the expedition, which were used to test instruments and set-up experiments, all samples originated from CTD-casts 1 through 11. Water samples were taken from the Niskin bottles eleven stations (Table 2.1) from different depths. We sampled several litres each from the mixed surface layer, the deep chlorophyll maximum (DCM), 300 m, 1,000 m and the deepest sample - taken some 50 m above ground - which was in most of the CTD stations 3-5 km deep. Samples were fixed in 1 % formaldehyde for 1 h or immediately processed for subsequent biomolecular investigations such as DNA isolation and metagenomics sequencing. This was achieved by fractionated filtration through 10 µm, 3 µm and 0.2 µm pore size polycarbonate filters. Filters were transferred to the -80° C freezer for subsequent isolation of nucleic acids at MPI Bremen followed by the sequencing of metagenomes or PCR-amplified 16S rRNA genes. A few 1 ml-aliquots of 0.2 µm filtrate were filtered through 0.02 µm to collect fixed, inactivated viruses. For bioarchiving purposes water samples were mixed with glycerol at a volume ratio of 4:1 and stored at -80° C.

The scholars did microscopic visualization and counting of marine bacteria using DAPI staining to determine total cell counts (TCC). They measured the depth distribution of TCC on each CTD station in five depths: the mixed layer (frequently 30 m), the DCM, 300 m, 1,000 m and in the deepest sample. During the course, we also performed cultivation on Zobell agar plates to determine in parallel the number of colony-forming units (CFU) in the surface water.

The scholars also performed single cell identification of bacteria by fluorescence *in-situ* hybridization (FISH) with fluorescently labeled rRNA targeted oligonucleotide probes targeting e.g. *Flavobacteriia*, *Gammaproteobacteria*, and members of the alphaproteobacterial clade SAR11, which is the most abundant heterotrophic bacterial group in the oceans.

Laboratory experiments also included substrate incubations of live surface microbiomes with three fluorescently labeled polysaccharides (FLAPS). Fluorescein-labeled laminarin, fucoidan and chondroitin sulfate were added with a final monomer concentration of 3.5 µM to two 1-L bottles each of surface water of Stations 7, 15, 25, 29, equivalent to CTDs 3, 5, 8 and 9. One bottle of each polysaccharide substrate was fixed in formaldehyde (1% final concentration for 1 hour at room temperature), and thereby prepared for subsequent flow cytometric sorting in the home laboratory on a 0.2 µm filter. One liter each was filtered through 0.2 µm filters, to prepare the sample for subsequent sequence analysis. Onboard, the uptake of the three different FLAPS substrates was microscopically visualized on fixed cells using DAPI as counterstain.

Tab. 2.1: Complete list of samples collected in the Marine Microbiology module

Station	Depth [m]	CTD bottle	Sample	Quantity	Purpose
2	30, 60, 300, 1000, 2000	22, 21, 16, 9,1	Filter	5	FISH and TCC
2	30 m	22	Filter	3	Genomic analyses
4	30, 50, 300, 1000, 5000	22, 21, 26, 8, 1	Filter	5	FISH and TCC
4	30	22	Filter	3	Genomic analyses
7	30, 90, 300, 1000, 4800	22, 20, 15, 13, 1	Filter	5	FISH and TCC
7	30	22	Filter	4	Genomic analyses + Virus filter
7	30	22	Filter	6	FLAPS experiment (3 fixed, 3 unfixed filters)
10	30, 100, 300, 1000, 3300	22, 20, 16, 13, 1	Filter	5	FISH and TCC
10	30	22	Filter	4	Genomic analyses + Virus filter
15	25, 52, 300, 1000, 4240	22, 20, 16, 8, 1	Filter	5	FISH and TCC
15	25	22	Filter	4	Genomic analyses + Virus filter
15	25	22	Filter	6	FLAPS experiment (3 fixed, 3 unfixed)
17	25, 50, 300, 1000, 4400	22, 20, 15, 7, 1	Filter	5	FISH and TCC
17	25	22	Filter	4	Genomic analyses + Virus filter
20	30, 45, 300, 1000, 3600	22, 20, 14, 7, 1	Filter	5	FISH and TCC
20	30	22	Filter	4	Genomic analyses + Virus filter
25	30, 60, 300, 1000, 5500	22, 20, 16, 7, 1	Filter	5	FISH and TCC

Station	Depth [m]	CTD bottle	Sample	Quantity	Purpose
25	5500	1	Seawater	2 x 50 ml	Colaboration with Prof. Dr. Rossello-Mora
25	300, 1000, 5500	16, 7, 1	Seawater	3 x 10 ml	Colaboration with Prof. Dr. Jens Harder
25	30	22	Filter	4	Genomic analyses + Virus filter
25	30	22	Filter	6	FLAPS experiment (3 fixed, 3 unfixed)
29	30, 45, 300, 1000, 4700	16, 14, 8, 2, 1	Filter	6	FISH and TCC
29	30	16	Filter	4	Genomic analyses + Virus filter
29	30	16	Filter	6	FLAPS experiment (3 fixed, 3 unfixed)
31	10, 30, 50, 80, 120, 200, 300, 650, 1000, 4600	20, 19, 17, 15, 14, 12, 11, 7, 6, 1	Filter	10	FISH and TCC
31	30, 300	19, 11	Filter	7	Genomic analyses + Virus filter (only 30 m)
31	10, 30, 50, 80, 120, 200, 300, 1000, 4600	20, 19, 17, 15, 14, 12, 11, 6, 1	Seawater	9 x 10 ml	Colaboration with Prof. Dr. Jens Harder
31	80, 300, 4600	15, 11 ,1	Seawater particles	250, 500, 250 ml	Colaboration with Prof. Dr. Jens Harder
33	30, 50, 300, 1000, 3700 m	21, 17, 10, 7, 1	Filter	5	FISH and TCC
33	30 m	21	Filter	4	Genomic analyses + Virus filter
33	300, 1000 m	10, 7	Seawater	2x 10 ml	Colaboration with Prof. Dr. Jens Harder

Aerosol and seawater sampling

Seawater samples were collected from the upper 1000 m of the water column at each CTD station during the cruise. These samples were filtered (0.45 µm) directly from the Niskin bottles on the rosette using an Acropak filter, with 5 L samples being collected from the surface bottle and 1 L samples being collected from 5 or 6 further depths at each station. Sample bottles had been acid washed before use and were double bagged and stored at room temperature for transportation back to the University of Oxford. A summary of the water samples collected is given in Table 2.2.

Tab. 2.2: Summary of water sampling for thorium isotope analysis during PS132

CTD Station	Date	Latitude [°]	Longitude [°]	Depth of 5L sample [m]	Depths of 1L samples [m]
1	03/09/2022	47.93	-8.66	10	60, 200, 300, 500, 1000
2	04/09/2022	43.50	-11.628	10	50, 120, 300, 500, 1000
3	06/09/2022	35.50	-13.855	10	90, 150, 300, 500, 1000
4	08/09/2022	30.00	-15.00	10	100, 150, 300, 500, 1000

CTD Station	Date	Latitude [°]	Longitude [°]	Depth of 5L sample [m]	Depths of 1L samples [m]
5	12/09/2022	14.551	-20.986	10	52, 120, 350, 500, 1000
6	14/09/2022	8.48	-19.467	10	50, 120, 300, 460, 850, 1000
7	16/09/2022	0.00	-15.00	10	45, 100, 200, 300, 800, 1000
8	21/09/2022	-10.00	0.00	10	60, 120, 200, 300, 800, 1000
9	24/09/2022	-20.25	6.35	10	45, 100, 200, 300, 800, 1000
10	26/09/2022	-25.83	9.70	10	50, 120, 200, 300, 650, 1000

Two high-volume aerosol samplers were installed on the forward rail of the Monkey Island. Electrical anemometer. Wind speed and direction was continuously monitored by this unit and the collectors were automatically switched off when the wind speed was less than 2 m s^{-1} or from a bearing between 150 and 280 degrees, relative to the ship's bow. In this way, sampling of emissions from the ship's stack was avoided.

The collectors were both equipped with Sierra-type cascade impactor sampling heads for the separation of different aerosol size fractions during collection. Samples will be analyzed in two fractions (< 1 µm & > 1 µm). Collection substrates in one collector were of acid-washed Whatman 41 cellulose for analysis of trace metals, while the other collector used washed and ashed glass fibre substrates for analysis of soluble ions and organic substances. These analyses will be conducted at the University of East Anglia.

Communication & Ocean Literacy Outreach

During the expedition scholars learned how to communicate scientific knowledge through onboard seminars, presentations and various outreach activities. One such outreach activity was the miniboat project in collaboration with the not-for-profit organization Educational Passages. School children from Germany, Ireland, South Africa, and Spain assembled small boats equipped with GPS and temperature sensors which were then deployed from *Polarstern*. The preparation and deployment of the miniboats were presented to the students virtually via video calls. Scholars shared their onboard experiences, and awareness of the oceans and climate change were transferred directly to the classroom. Other outreach activities included creating content for social media outlets and designing an Instagram account for NF-POGO Centre of Excellence for Observational Oceanography.

Preliminary (expected) results

Oceanography

The expedition from Bremerhaven to Cape Town covered an enormous geographic range as we transit through temperate and sub-tropical regions. During the transect, participants were trained in the principles of oceanographic, meteorological, and atmospheric interactions and their impacts on climate.

The gained data allowed the scholars to categorise regional oceanic and atmospheric patterns and identify biogeographic provinces of the Atlantic.

Bio-optical properties of the total particulate matter along the North-South Atlantic transect

Water components such as phytoplankton, Coloured Dissolved Organic Matter (CDOM), and non-algal particles affect the optical variability of the upper layer of the ocean. The absorption properties of these components are thus used to assess changes in phytoplankton composition and for the evaluation of primary production models based on remote sensing data. The absorption coefficients of total particulate matter (a_p (λ)) in seawater samples collected at ten stations on board the *Polarstern* were measured. The latitudinal and vertical variability of a_p (434), a_p (670), B/R ratio, and normalized particulate absorption spectral shape at each station was analyzed and the normalized a_p (λ) curves were classified into three levels: Surface (10 m), Deep Chlorophyll Maximum (DCM) and the layer below the observed differences between the absorption coefficient of particulate matter and its spectral shape confirm that a_p (λ) variability depends on physicochemical conditions of the medium (e.g. radiant energy, nutrient concentration, and temperature), Fig. 2.4.

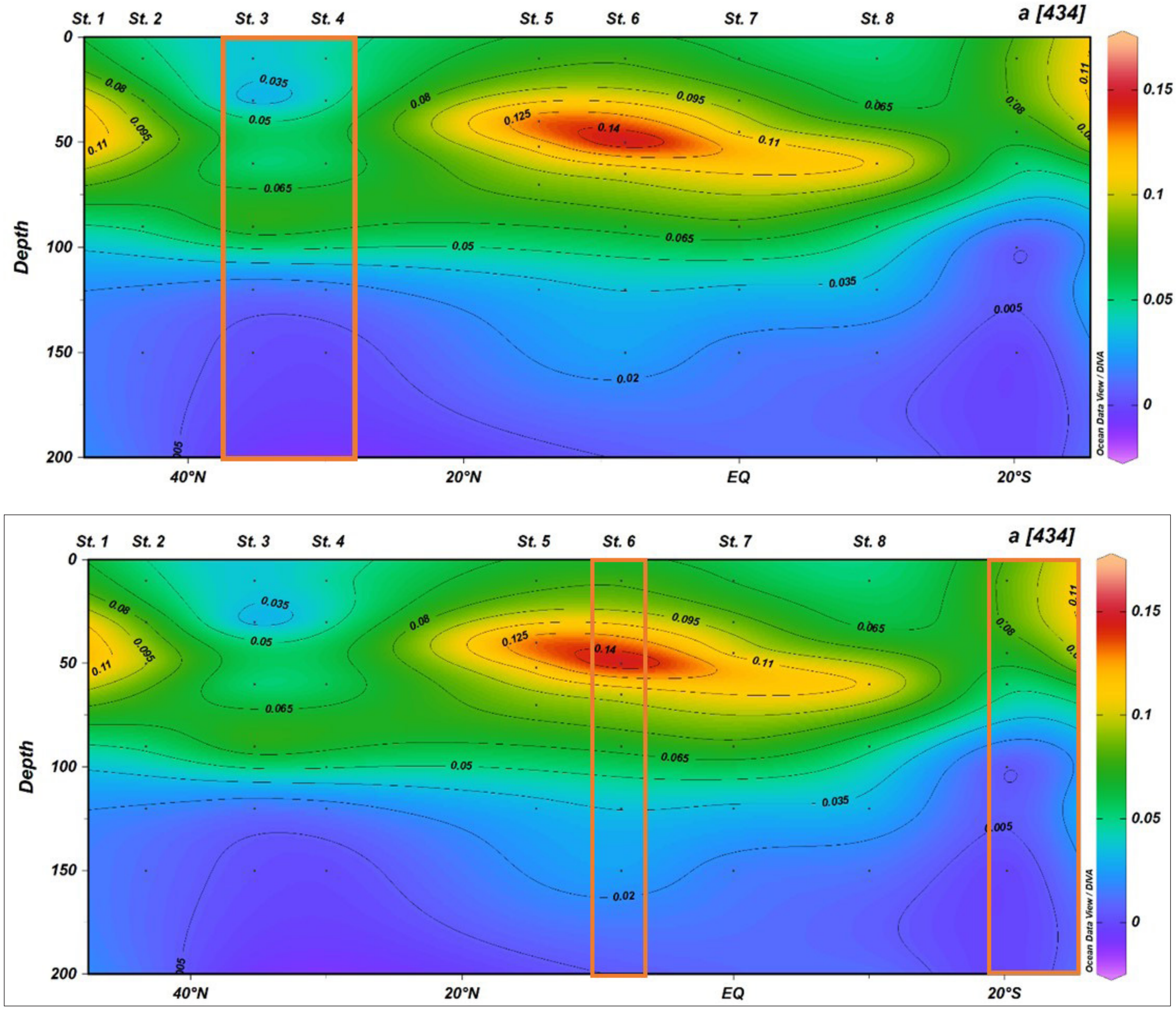


Fig.2.4: Absorption coefficients of total particulate matter along the NoSoAt transect (lowest and highest a_p (434) marked); in the surface, a_p (434) varied between 0.036 m^{-1} and 0.111 m^{-1}. In the DCM and the subsequent depth, a_p (434) varied between 0.052 m^{-1} and 0.164 m^{-1}, and between 0.010 m^{-1} and 0.095 m^{-1}, respectively. Stations 3 (30ºN) and 4 (35ºN) showed the minimum values for a_p (434) and a_p (670) associated to a downwelling of warm water from the surface, whereas stations 6 (8ºS), 9 (20ºS), and 10 (25ºS) showed the highest values due to local conditions.

xBT - Temperature profiles along the transect

During the expedition 15 xBT measurements were done and analyzed. Figure 2.5 shows temperature profiles at the different latitudes in Northern and Southern Hemispheres. The variation of the mixed layer depth is from 20 to 50 m in the Northern Hemisphere and up to 120 m in the Southern Hemisphere, which is agreed with the mean September mixed layer depth according to World Ocean Atlas and FESOM output (Fig. 2.6).

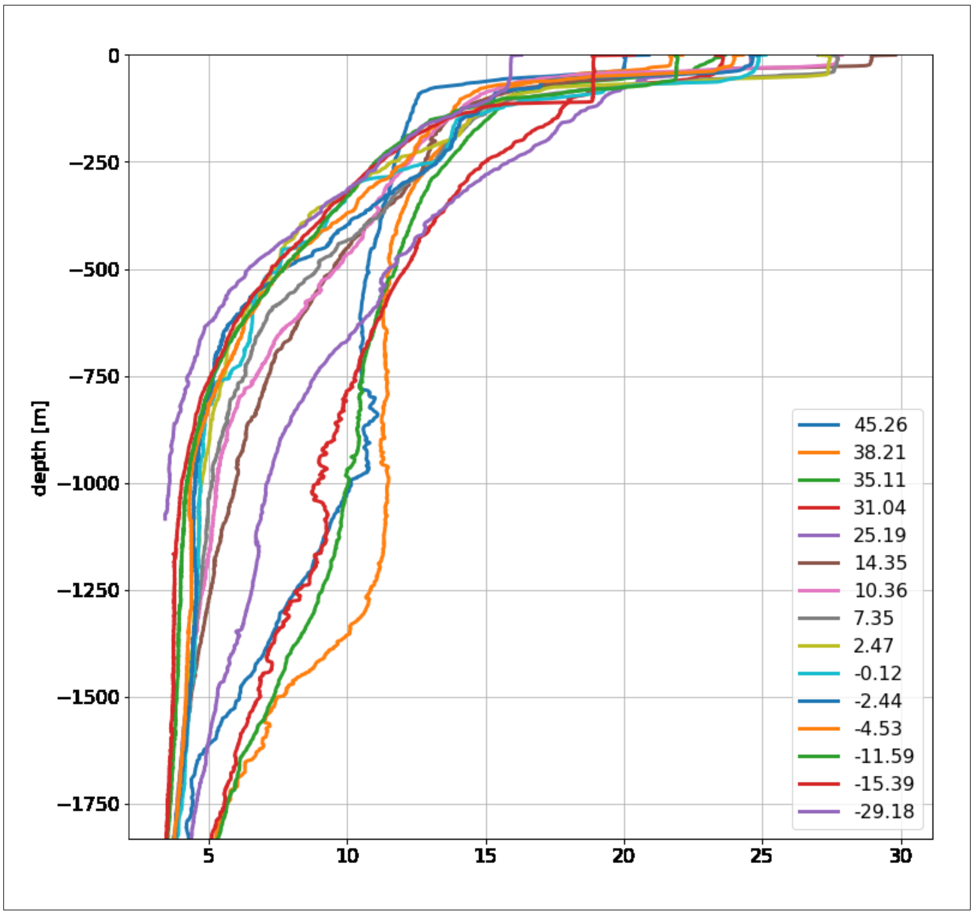


Fig. 2.5: Temperature profiles measured using xBT during PS132;
the numbers attributing to each colour identify the latitude of the measurements

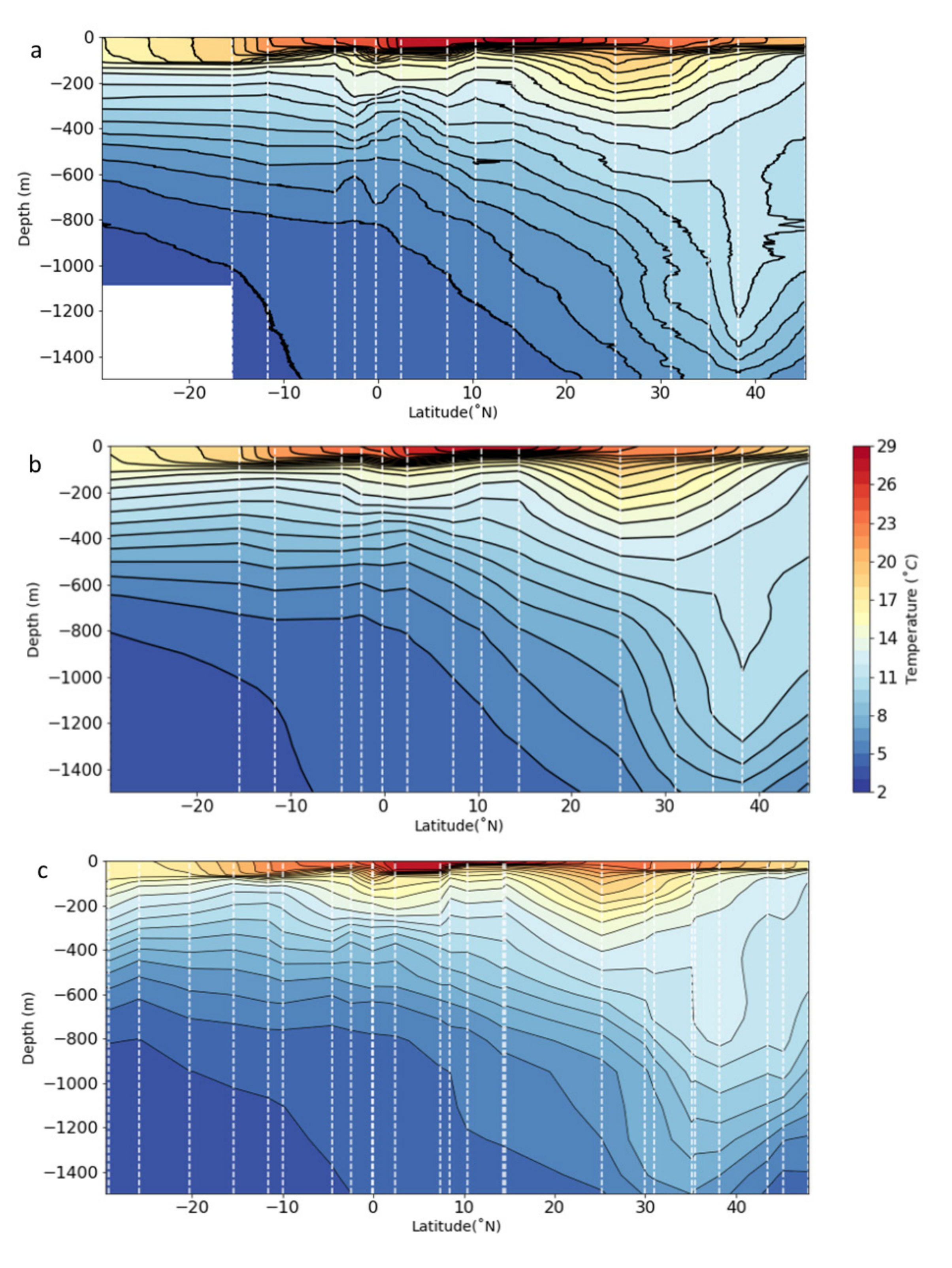


Fig. 2.6: Water temperature profiles (a) measured using xBT probes along the cruise transect, (b) mean for September along the cruise transect obtained from reanalysis, in particular, from World Ocean Atlas 2018, (c) mean simulated by FESOM on NG5 mesh

As expected we observed a relatively deep thermocline at the edge of the subtropical gyre as a result of Ekman pumping and a relatively shallow thermocline at the Equator as a result of Equator upwelling. The modelling results show the same patterns (Fig. 2.6). However, the position of the core of the Mediterranean Outflow water masses is shifted in FESOM results compared to the observations. It is situated between 600 and 1,000 m depth in the modelling simulations and between 800 and 1,200 in the observations. Also, the modelling output provides a relatively narrower core compared to the observations. One of the reasons of such a discrepensy is the relatively coarse vertical resolution at the mentioned vertical horizon. The other possible reasons should be further studied.

ADCP -Velocity profiles along the transect

During the expedition the ADCP measurements were collected and analyzed during 11 CTD stations (Fig. 2.7). The ADCP data show the development of the Ekman spiral nearly at half of the stations. Additionally, ADCP measurements allow to trace the dominant near-surface current system in the area. As an example, Figure 2.5 demonstrates mean vertical profile of the horizontal velocities during CTD station time at the position Nº 05 (14° 33,16’ N and 20° 59,19’ W), nearby Canarian Islands. The Ekman’s spiral presents at first 30-50 m and below there is clear footprint of the Canarian current system. The magnitude of velocities are from 0.7 to 0.5 m s^{-1} along the Ekman spiral, decreasing from the top to the bottom. Below 50 m, a nearly homogenous velocity profile in a sense of magnitude and direction with a magnitude of about 0.3 m s^{-1} was recorded.

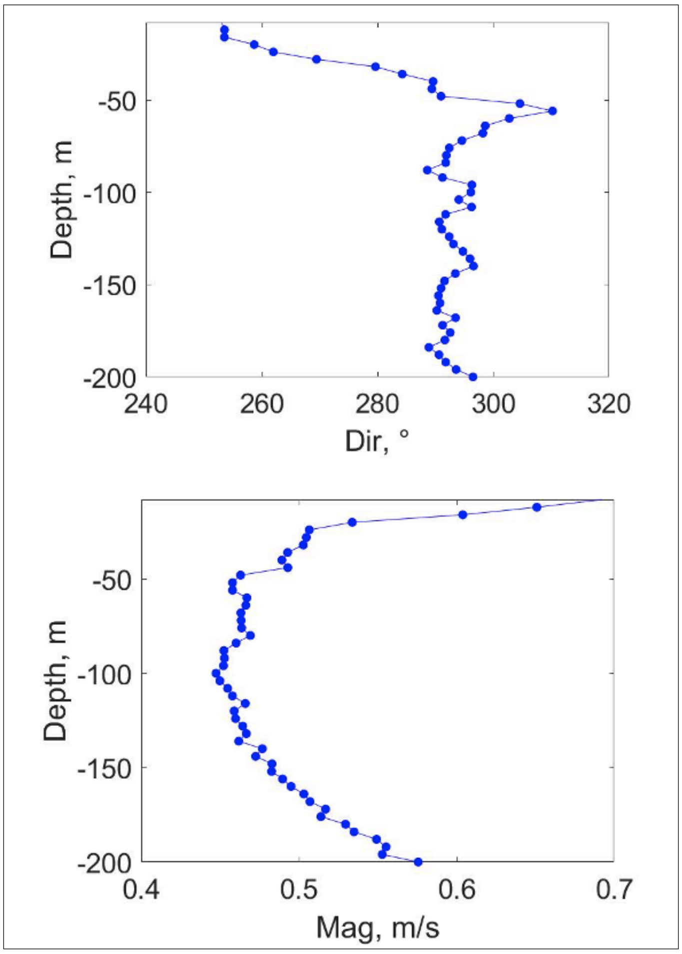
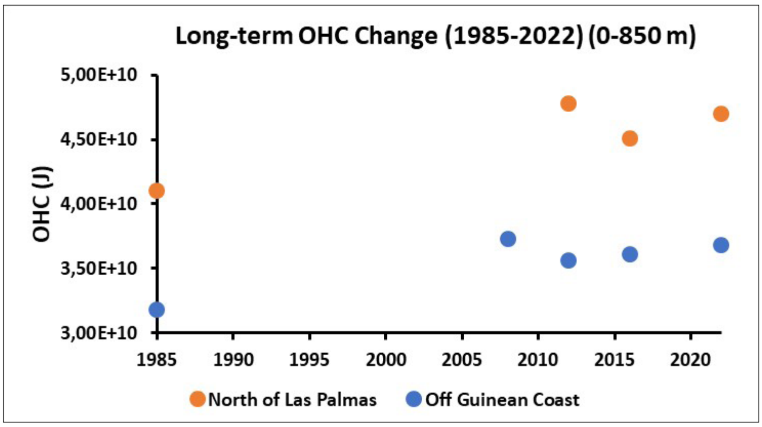


Fig. 2.7: Mean (averaged over the CTD station time) vertical profile of the horizontal velocity near by Canarian Islands. Upper panel: direction, °; Low-panel: magnitude, m/s

Long-term change in heat content

In order to understand the response of the Eastern Atlantic Ocean, we calculated the ocean heat content (OHC) of five CTD stations of the PS132 transect (NoSoAT 2022). We also computed and compared how much heat the ocean (at these stations) has absorbed spanning up to 37 years (1985 – 2022). The OHC was calculated as the vertical integral of temperature multiplied by the seawater density and specific heat capacity. With archival data constraints, the stations selected include locations off the Strait of Gibraltar, North of Las Palmas, off the Guinean Coast, at the Equator and off the Angolan coast. Over a short-term range (2008 – 2022) from surface to maximum depth, the station off the Angolan coast has accumulated the highest heat between 2012 and 2022 by 2,499 x 10^{10} Joules. This can be attributed to the heat source from the Indian Ocean through the Agulhas Leakage (Lee et al., 2011). The second warmest, station off the Strait of Gibraltar, increased by 1,720 x 10^{10} J but it is highly influenced by the Mediterranean Outflow Water (MOW). On a long-term range (1985 – 2022) over the upper ocean (0 – 850 m), the stations North of Las Palmas and off Guinean Coast have warmed by about 5,960 x 10^9 J. With a special focus on the MOW, we observed a currently cooling water mass with a strong variability over the years studied. A considerable amount of heat stored by the ocean over the years is apparent in the changing temperature profiles, but further studies need to be conducted on the impact of the MOW on the Atlantic Ocean.



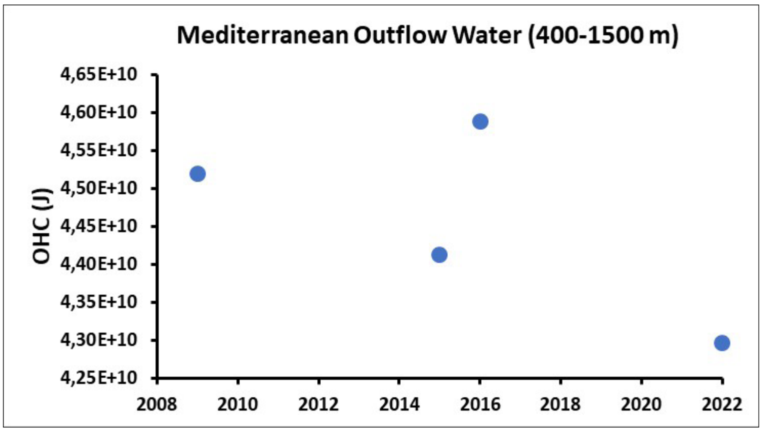


Fig. 2.8: Long-term trends in Ocean Heat Content at North of Las Palmas, off the Guinean Coast and at the Mediterranean Outflow

Bacterioplankton

We used oceanic provinces *sensu* Longhorst (Longhurst, 2007) to predict patterns related to the trophic level, i.e., green vs. blue waters. The latitudinal North-South Atlantic transect covered by PS132 included eleven CTDs from the following Longhurst provinces: NADR (North Atlantic Drift province), NAST (North Atlantic Subtropical), CNRY (Canary Current/Upwelling), ETRA (Eastern Tropical Atlantic), SATL (South Atlantic gyre province), BENG (Benguela Current/Upwelling). We hypothesized that the green/blue water pattern along PS132 would be reflected in more/fewer bacteria (TCC), respectively. Green waters were expected to have higher relative abundances of typical heterotrophic groups such as *Flavobacteriia* and *Gamma*proteobacteria compared to blue water. SAR11 abundances should be higher in blue waters under oligotrophic conditions.

1. Total cell counts (TCC) as determined microscopically showed the expected depth distribution with 1.0-1.5 x 10^6 cells/ml^{-1} in the mixed layer, 0.7 to 1.4 x 10^6 cells/ml^{-1} in the DCM, 2-4 x 10^5 cells/ml^{-1} at 300 m, ~ 10^5 cells/ml^{-1} at 1000m and as little as 3 x 10^4 cells/ml^{-1} in the deepest samples. CTD #10 from the Benguela upwelling showed the highest cell counts of 2.5 Mio cells/ml^{-1} in the mixed layer. A summary of all preliminary counts is presented in Figure 2.9.

2. By fluorescence *in-situ* hybridization we performed single cell identification of fixed bacterial cells on polycarbonate filters. The differentiation of rather copiotrophic Flavobacteriia and Gammaproteobacteria from oligtrophic bacteria of the clade SAR11 showed patterns which were consistent with the Longhurst provinces. With a SAR11-targeted mix of oligonucleotide probes we could, e.g., detect high numbers of SAR11 (53 % of TCC) at the equator whereas probes CF319a and GAM42a remained consistently below 10 %.

3. We performed substrate uptake experiments for heterotrophic bacteria with three different glycans. Surface water samples were incubated for 3 days (in one case, CTD #5, 6 days) in 1 L-bottles in the dark at room temperature. Substrate incubations with fluorescein-labelled laminarin, a homoglucan used by diatoms as main storage molecule, resulted in microscopically detectable staining of about 5-10 % of all cells. Also, fluorescein-labelled fucoidan, a fucose-containing sulphated polysaccharide, and fluorescein-labelled chondroitin sulphate that is used as a source of organic C and N stained ~5 % of the cells. In the later incubations, we detected conspicuous FLAPS-positive cells reminiscent of planctomycetes, which had enriched during a 6-day incubation of surface water taken at CTD-station 6.

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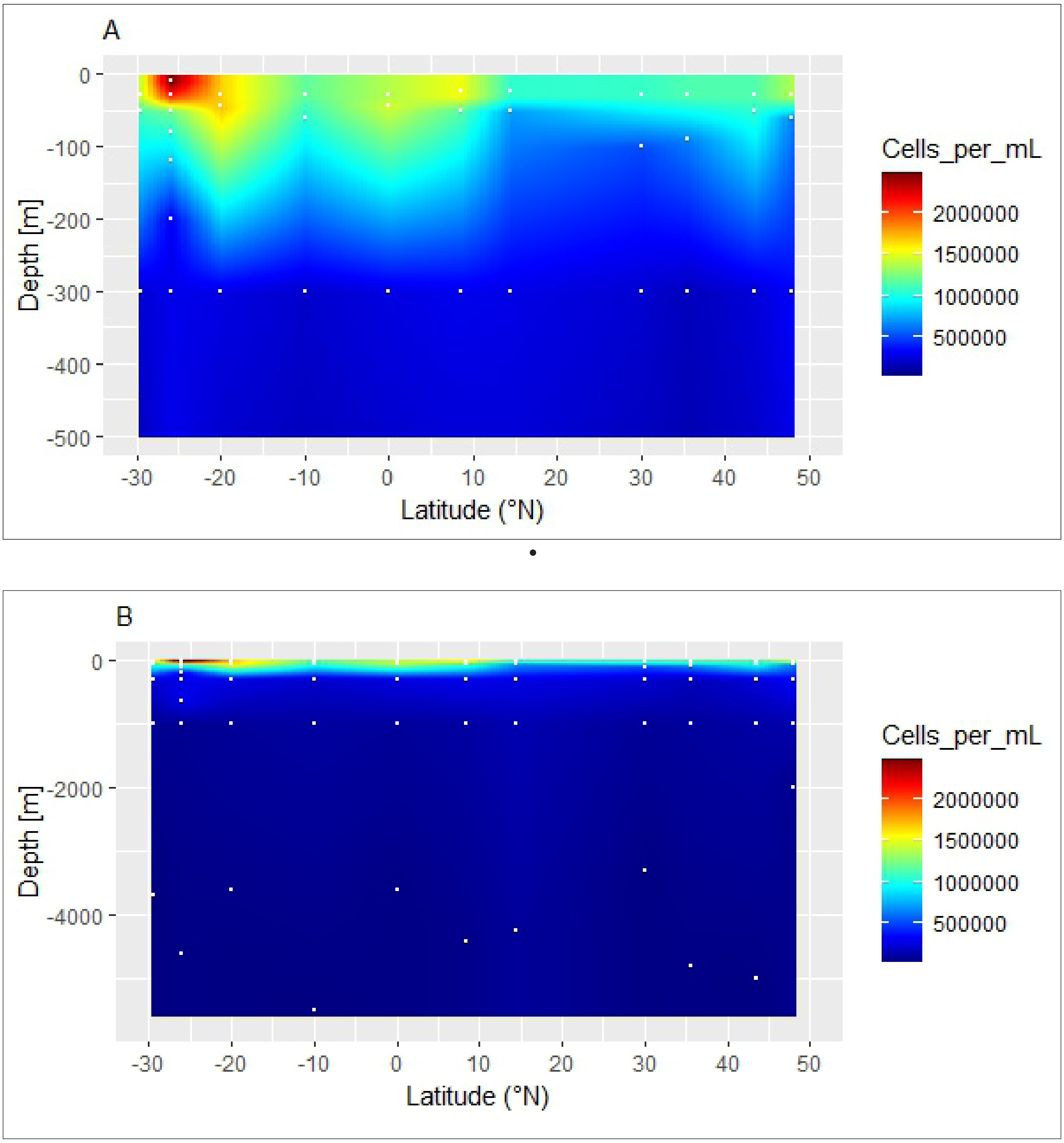

Fig. 2.9: Depth profiles of total cell counts (TCC) along the North-South Atlantic Transect PS132. High numbers were found in surface waters with an exponential decrease with depth.
***A** TCC in the first 500 m water depth; **B** Maximal depth profile of TCC.*

Aerosol and seawater sampling

Aerosol collection periods are summarized in Table 2.3 and Figure 2.10.

Orange/brown colouration was observed on the > 1 µm fractions of aerosol samples 7 and 8, which is indicative of the presence of Saharan dust in these samples. This is typically associated with higher level atmospheric transport of dust, which then enters the surface atmosphere through gravitational settling. For much of the period 7 – 13 September, the surface wind direction coincided with the ship's course, so that the aerosol collectors were disabled by the wind sector controller.

Samples 11–16 contained noticeable amounts of soot, with the highest amounts apparent in sample 14. The most likely source of this material is biomass burning in southern Africa, as southern hemisphere spring is the peak burning season in this region. Samples will be analyzed for tracers of biomass burning (e.g. excess potassium) in order to test this hypothesis.

Faint orange/brown colouration was also noticeable on the larger size fractions of samples 17 & 18. Surface winds were southeasterly during this period and the Namib Desert may be a potential source for this material.

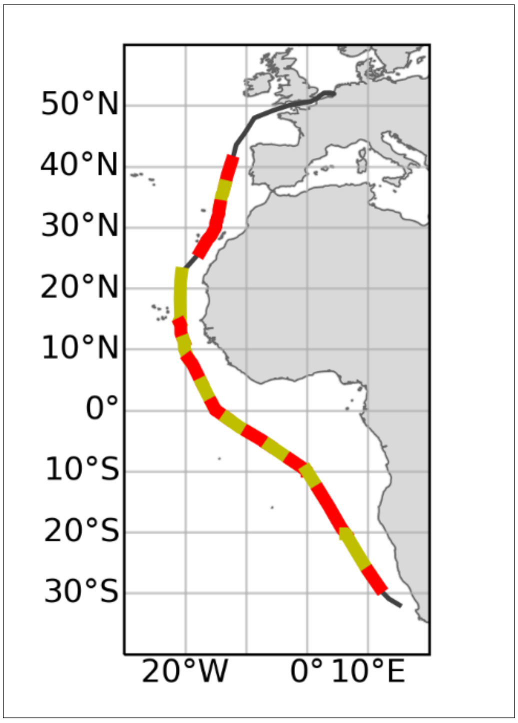

Fig. 2.10: Track of PS132, showing aerosol sampling periods as alternating red and yellow bars

Tab. 2.3: Summary of aerosol collection periods during PS132 and pump operation times for the trace metal sampler; samples with pump times of 0 hr were blanks.

Sample Number	Start Date	Start Lat [°]	Start Lon [°]	End Date	End Lat [°]	End Lon [°]	Pump Time [hr]
1	02/09/2022			02/09/2022			0
2	03/09/2022			05/09/2022			0
3	05/09/2022	40.59	-12.44	06/09/2022	37.18	-13.41	22.48
4	06/09/2022	36.77	-13.52	07/09/2022	33.63	-14.29	21.34
5	07/09/2022	33.45	-14.33	09/09/2022	25.93	-17.54	5.05
6	09/09/2022	25.94	-17.53	10/09/2022	22.50	-20.58	0
7	10/09/2022	22.41	-20.60	12/09/2022	14.31	-20.86	7.76
8	12/09/2022	14.16	-20.78	13/09/2022	11.39	-20.21	23.14
9	13/09/2022	11.30	-20.18	14/09/2022	8.37	-19.45	22.36
10	14/09/2022	8.34	-19.36	15/09/2022	4.55	-17.31	11.55
11	15/09/2022	4.41	-17.23	16/09/2022	1.10	-15.57	21.54
12	16/09/2022	0.97	-15.50	17/09/2022	-1.27	-13.16	23.1
13	17/09/2022	-1.34	-13.05	18/09/2022	-3.56	-9.70	23.2

Sample Number	Start Date	Start Lat [°]	Start Lon [°]	End Date	End Lat [°]	End Lon [°]	Pump Time [hr]
14	18/09/2022	-3.64	-9.57	19/09/2022	-5.72	-6.22	22.88
15	19/09/2022	-5.82	-6.08	20/09/2022	-8.06	-2.78	22.99
16	20/09/2022	-8.17	-2.61	21/09/2022	-10.00	0.00	21.6
17	21/09/2022	-10.00	0.00	22/09/2022	-13.08	1.95	23.88
18	22/09/2022	-13.25	2.05	24/09/2022	-20.25	6.35	46.51
19	24/09/2022	-20.25	6.35	26/09/2022	-26.54	10.18	46.32
20	26/09/2022			27/09/2002			

Communication & Ocean Literacy Outreach

In terms of social media engagement in total 11 posts with #NoSoAT were found done by xx users. There were 297 engagements including likes, retweets and comments, 12,242 impressions and 688 interactions. All 11 posts were retweeted.

Videoconferences involved schools in four countries (Germany, Ireland, Spain and South Africa). It was estimated that these audiences included over 100 school children from ages between nine and 18 years old. Furthermore, *Polarstern* had a live conversation with the sustainability week of the island of Sylt. Chief Scientist Prof Karen Wiltshire and Prof. Peter Lemke were invited and conducted a live talk at Erlebniszentrum Naturgewalten Sylt, Germany).

21 blog posts in the "follow-*Polarstern*.de" were written documenting the training programme, live on board as well as the experiences of the scholars on board. The blog posts were published in the *Polarstern*-App (https://follow-*Polarstern*.awi.de/#main-menu) in English and German.

Data management

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

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

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

This expedition was supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 4, Subtopic 2.

In all publications based on this expedition, the **Grant No. AWI_PS132_01** will be quoted and the following publication will be cited:

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

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Boetius A (2019) Global change microbiology – big questions about small life for our future. Nature Reviews Microbiology, 17, 331-332. Ferguson RL, Buckley EN, Palumbo AV (1984) Response of marine bacterioplankton to differential filtration and confinement. Applied Environmental Microbiology, 47:49–55.

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3. BATHYMETRIC UNDERWAY MEASUREMENTS

Yvonne Schulze Tenberge, Kolja Dorschel, Patrick Schwarzbach,
not on board: Boris Dorschel
DE.AWI

Grant-No. AWI_PS132_03

Objectives

Accurate knowledge of the seafloor topography, hence high-resolution bathymetry data, is key basic information necessary to understand many marine processes. It is of particular importance for the interpretation of scientific data in a spatial context. Bathymetry, or geomorphology, is a basic parameter for the understanding of the general geological setting of an area and geological processes such as erosion, sediment transport and deposition. Even information on tectonic processes can be inferred from bathymetry. Supplementing the bathymetric data, high-resolution sub-bottom profiler data of the top 10 s of meters below the seabed provide information of the sediment architecture and the lateral extension of sediment successions. This can be used to study depositional environments on larger scales in terms of space and time, of which the uppermost sediments may be sampled.

While world bathymetric maps give the impression of a detailed knowledge of worldwide seafloor topography, most of the world's ocean floor remains unmapped by hydroacoustic systems. In these areas, bathymetry is modelled from satellite altimetry with a corresponding low resolution. Satellite-altimetry derived bathymetry therefore lack the necessary resolution to resolve small- to meso-scale geomorphological features (e.g. sediment waves, glaciogenic features and small seamounts). Ship-borne multibeam data provide bathymetry information in a resolution that is sufficient to resolve those features.

Therefore, the main tasks of the bathymetry group on board *Polarstern* during PS132 were:

- collection of bathymetric data, including calibration and correction of the data for environmental circumstances (sound velocity, systematic errors in bottom detection, etc.)
- post processing and cleaning of the data
- data management for on-site map creation

Work at Sea

Technical description

During the PS132 cruise, the bathymetric surveys were conducted with the hull-mounted multibeam echosounder (MBES) Teledyne Reson HYDROSWEEP DS3. The HYDROSWEEP is a deep-water system for continuous mapping with the full swath potential. It operates on a frequency of ~14 kHz. On *Polarstern*, the MBES transducer arrays are arranged in a Mills cross configuration of 3 m (transmit unit) by 3 m (receive unit). The combined motion, position (Trimble GNSS), and time data comes from an iXBlue Hydrins system and the signal is directly transferred into the Processing Unit (PU) of the MBES to carry out real-time motion compensation in Pitch, Roll and Yaw. With a combination of phase and amplitude detection algorithms the PU computes the water depth from the returning backscatter signal. The system can cover a sector of up to 140° with 70° per side. In the deep sea, an angle of ~50° to both sides could be achieved.

Data acquisition and processing

Data acquisition was carried out throughout the entire cruise between Bremerhaven and Cape Town where allowed.

The MBES was operated with Hydromap Control and for online data visualization, Teledyne PDS was used. The collected bathymetry was stored in ASD and S7K raw files.

Subsequent data processing was performed using Caris HIPS and SIPS. For generating maps, the data were exported to QGIS in the GeoTIFF raster format.

Sound velocity profiles

For best survey results with correct depths, the HYDROSWEEP was calibrated with sound velocity profiles from CTD and XBT operations obtained by the other science groups (for details see Chapter 1). Additionally, these profiles were combined/extended with World Ocean Atlas 2018 data to create full ocean depth SV profiles.

Tab. 3.1: Stations

Station Number	Device	Action	Event Time [UTC]	Latitude	Longitude
PS132_0_underway_13	Hydrosweep DS3	station start	02.09.2022 08:10:00	50°19.002’N	001°17.006’W
PS132_0_underway_13	Hydrosweep DS3	profile start	02.09.2022 08:10:01	50°19.000’N	001°17.011’W
PS132_0_underway_13	Hydrosweep DS3	profile end	27.09.2022 21:00:00	30°32,366’S	013°03,225’E
PS132_0_underway_13	Hydrosweep DS3	station end	27.09.2022 21:00:00	30°32,366’S	013°03,225’E

Preliminary Results

During 26 days of survey, a track length of 5,758 nm (10,663 km) was surveyed by the swath bathymetry. Figure 3.1 shows the generated bathymetry grid over the Atlantic.

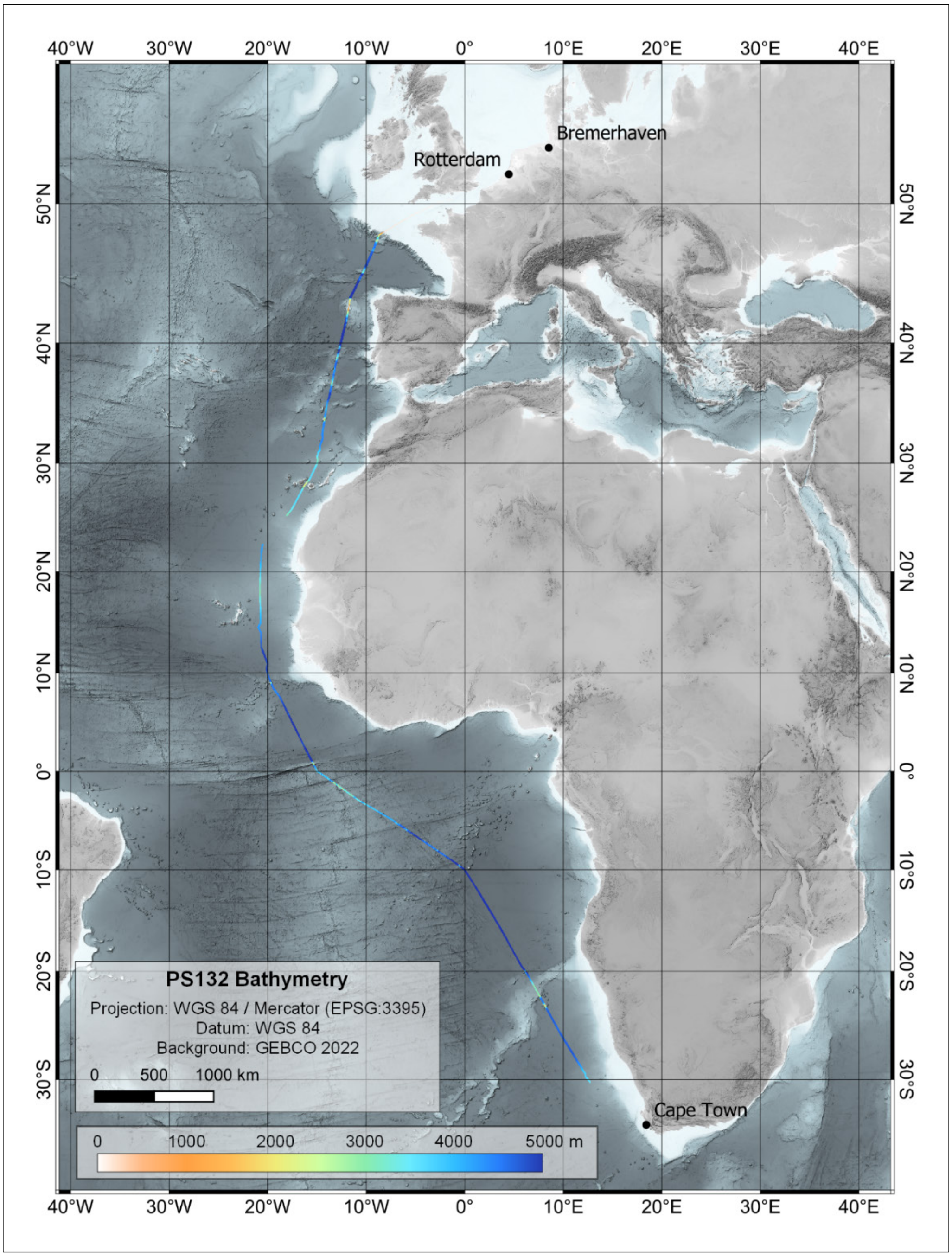

Fig. 3: Overview on the bathymetric data acquired during PS132

Data management

Bathymetric data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the cruise at the latest. By default, the CC-BY license will be applied. Furthermore, the data will be provided to the Nippon Foundation – GEBCO Seabed 2030 project.

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

In all publications based on this expedition, the **Grant No. AWI_PS132_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.

4. CARBONYL SULFIDE AND CARBON DISULFIDE EMISSIONS (COS-AT)

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not on board: Sinikka Lennartz[1]

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Grant-No. AWI_PS PS132_04

Outline

Sulfur containing trace gases impact Earth's climate, and the ocean is a major natural source for the most abundant sulfur gas in the atmosphere, carbonyl sulfide (COS), and its precursor carbon disulfide (CS2). Understanding and quantifying COS oceanic emissions is critical in two contexts: First, COS directly influences the aerosol formation in the stratosphere, which impacts the radiative budget of the Earth. Second, COS is a proxy for terrestrial CO2 uptake by plants. A large gap in the atmospheric budget of COS currently impedes conclusions about trends in stratospheric aerosol formation and gross primary production on a global level. Especially marine emissions are associated with very high uncertainties. During this cruise, we performed the first measurements of stabile isotope ratios for COS and CS2 in seawater and marine boundary layer in the open Atlantic, in order to establish a first isotopic signature of oceanic emissions and thus constrain the relative role of ocean emissions with a mass balance approach. In addition, we continuously measured COS concentration in seawater and the marine boundary layer, to quantify the relationship between photochemical production of COS. Samples of dissolved organic matter (DOM) were taken twice daily for subsequent analysis of the molecular composition of the large precursor pool for COS photo- and dark production.

Objectives

The overall objective was to further constrain the role of marine emissions in the atmospheric budget of carbonyl sulphide. In particular, the following objectives were addressed:

1. *Determining spatial and temporal patterns of stable isotope ratios of seawater and marine boundary layer COS and CS2 and their covariations with physicochemical parameters along the transect:*

For five different biogeochemical regimes along the transect, we took samples to determine the isotopic sulphur ratio of COS and CS2 in the surface ocean at three times of the day and the following morning (i.e. a full diel cycle). To cover the full diurnal cycles that results from photochemical production, samples will be taken before sunrise, in the afternoon and after sunset. In order to cover spatial variability, full diel cycles have been sampled at locations that vary in physicochemical parameters such as temperature and satellite chlorophyll as a proxy for ocean productivity. Covariations with the composition of the DOM pool (parameters listed below) and other physicochemical parameters will be determined after samples have been analyzed in land-based laboratories.

2. *Determining spatial patterns of production rates of seawater COS production and their covariations with the large precursor pool of dissolved organic matter:*

Both trace gases are produced by photochemical reactions of dissolved organic matter in seawater. Productions rates will be estimated from continuous underway measurements of COS concentration along the transect using a model established by Lennartz et al. (2017), and related to characteristics of the marine DOM pool, including the parameters listed below. Alternating continuous measurements between seawater and air have been measured to calculate emissions along the transect. Since a common production pathway of COS and carbon monoxide (CO) has been proposed (Pos et al., 1998), we have measured CO concentrations as well, to assess similarities and differences in production rates with COS. Rates are obtained from continuous measurements over full diurnal cycles.

Work at sea

The work plan on board included measurements, sampling and sample preparation for subsequent analysis after the cruise. For discrete measurements of stable isotope ratios (Objective 1), we have sampled the marine boundary layer directly from the ship's deck and equilibrated seawater with a custom-made equilibrator (headspace 5 L) after an equilibration time of 1h. Samples have been stored in coated canisters and are analyzed after the cruise. For Objective 3, we have performed continuous concentration measurements of COS and CO with laser absorption spectroscopy at a frequency of 1 Hz. The spectrometer was connected to an equilibrator that was supplied with seawater from the ship's internal seawater system. It alternated between seawater measurements and measurements of air from the marine boundary layer. In addition, underway samples for DOM have been taken twice a day (before sunrise and in the afternoon). Samples include the following parameters: dissolved organic carbon (DOC), solid-phase extractable dissolved organic matter (SPE-DOC), solid-phase extractable dissolved organic sulphur (SPE-DOS), optical properties such as chromophoric dissolved organic matter (CDOM) and fluorescent dissolved organic matter (FDOM). A list of all samples can be found in Table 4.1.

In addition, seawater for analysis of C14 radiocarbon dating of the BPCA-fraction (benzene polycarboxylic acids) was sampled, and solid-phase extracted onboard. DOM parameters have also been taken from CTD casts for deeper water layers. A list of samples is presented in Table 4.2.

Tab. 4.1: Samples taken during PS132 for the project COS-AT

Date	time (UTC)	Location		DOM: CDOM/ FDOM/ SPE-DOC/ SPE-DOS/ DOC	DMSP	CS_2	S-Isot. water	S-Isot. air
02.09.2022	04:30	50°31.83‘ N	00°02.02‘ W	√				
02.09.2022	15:00	49°57.81‘ N	03°05.06‘ W	√				
05.09.2022	15:15	40°39.50‘ N	12°24.87‘ W	√				
06.09.2022	06:20	38°07.43‘ N	13°11.25‘ W	√	√	√	√	
06.09.2022	15:15	36°35.76‘ N	13°33.44‘ W	√	√	√	√	√
06.09.2022	19:00	35°57.15‘ N	13°42.91‘ W	√	√	√	√	
07.09.2022	06:30	34°44.29‘ N	14°05.10‘ W	√	√	√	√	
07.09.2022	15:15	33°14.23‘ N	14°21.98‘ W	√				

Date	time (UTC)	Location		DOM: CDOM/ FDOM/ SPE-DOC/ SPE-DOS/ DOC	DMSP	CS_2	S-Isot. water	S-Isot. air
08.09.2022	06:30	30°46.00‘ N	14°56.77‘ W	√				
08.09.2022	16:00	29°40.22‘ N	15°10.98‘ W	√				
09.09.2022	06:40	27°27.04‘ N	16°38.27‘ W	√				
09.09.2022	15:30	26°05.64‘ N	17°26.54‘ W	√				
10.09.2022	06:50	23°59.79‘ N	19°15.73‘ W	√				
10.09.2022	15:45	22°32.65‘ N	20°32.67‘ W	√				
11.09.2022	06:50	19°31.03‘ N	20°47.58‘ W	√	√			
11.09.2022	16:00	17°37.15‘ N	20°48.36‘ W	√	√	√	√	√
11.09.2022	19:30	16°56.37‘ N	20°47.33‘ W	√	√	√	√	
12.09.2022	07:00	14°48.70‘ N	20°51.01‘ W	√	√	√	√	
12.09.2022	16:00	14°12.42‘ N	20°48.51‘ W	√				
13.09.2022	07:00	12°20.26‘ N	20°34.54‘ W	√				
13.09.2022	16:00	11°19.92‘ N	20°11.26‘ W	√				
14.09.2022	07:10	09°02.82‘ N	19°41.65‘ W	√				
14.09.2022	15:45	08°22.60‘ N	19°23.38‘ W	√				
15.09.2022	07:00	06°05.86‘ N	18°03.74‘ W	√	√	√	√	
15.09.2022	15:30	04°46.44‘ N	17°24.86‘ W	√	√	√	√	√
15.09.2022	19:10	04°12.03‘ N	17°08.03‘ W	√	√	√	√	
16.09.2022	06:50	02°25.82‘ N	16°15.51‘ W	√	√	√	√	
16.09.2022	15:45	01°03.81‘ N	15°33.04‘ W	√				
17.09.2022	06:20	00°20.44‘ S	14°27.14‘ W	√				
17.09.2022	14:45	01°11.30‘ S	13°15.93‘ W	√				
18.09.2022	06:35	02°45.49‘ S	11°03.62‘ W	√				
18.09.2022	15:20	03°32.10‘ S	09°44.46‘ W	√				
19.09.2022	06:20	04°50.82‘ S	07°30.57‘ W	√	√			
19.09.2022	15:15	05°41.63‘ S	06°15.40‘ W	√	√	√	√	√
19.09.2022	18:15	05°59.40‘ S	05°49.30‘ W	√	√	√	√	
20.09.2022	06:05	07°09.40‘ S	04°06.33‘ W	√	√	√	√	
20.09.2022	15:40	08°05.02‘ S	02°44.34‘ W	√				
21.09.2022	05:45	09°27.92‘ S	00°43.37‘ W	√				
21.09.2022	15:55	10°03.15‘ S	00°02.01‘ E	√				
22.09.2022	05:40	12°03.00‘ S	01°18.58‘ E	√	√	√	√	
22.09.2022	15:30	13°09.23‘ S	01°59.31‘ E	√	√	√	√	√
22.09.2022	18:50	13°42.96‘ S	02°20.11‘ E	√	√	√	√	
23.09.2022	05:35	15°34.65‘ S	03°29.39‘ E	√	√	√	√	
23.09.2022	15:15	16°49.48‘ S	04°12.40‘ E	√				
24.09.2022	05:25	19°00.35‘ S	05°27.84‘ E	√				

Date	time (UTC)	Location		DOM: CDOM/ FDOM/ SPE-DOC/ SPE-DOS/ DOC	DMSP	CS_2	S-Isot. water	S-Isot. air
24.09.2022	15:00	20°15.05‘ S	06°20.97‘ E	√	√	√	√	√
24.09.2022	17:30	20°15.06‘ S	06°21.03‘ E	√	√	√	√	
25.09.2022	05:10	21°53.16‘ S	07°19.38‘ E	√	√	√	√	
25.09.2022	15:30	23°42.15‘ S	08°24.56‘ E	√				
26.09.2022	04:45	25°46.67‘ S	09°40.08‘ E	√				
26.09.2022	15:15	26°43.74‘ S	10°18.69‘ E	√				

Tab. 4.2: Samples taken during PS132 for DOM analysis (NMR) and radiocarbon dating

Event number	CTD number	Date	Latitude	Longitude	Depth [m]	Niskin bottle number	Volume [l]
02-01	1	03.09.2022	47°55.8‘N	08°39.6‘W	2000	2, 3, 4, 5, 6	50
					1000	10, 11, 12, 13, 14	50
04-01	2	04.09.2022	43°30.0‘N	11°37.66‘W	5000	2, 3, 4, 5, 6	50
					1100	8, 9, 10, 11, 12	50
07-01	3	06.09.2022	35°30.0‘N	13°51.32‘W	4800	2, 3, 4, 5, 6	50
					1200	8, 9, 10, 11, 12	50
10-01	4	08.09.2022	30°00.0‘N	15°00.0‘W	3300	2, 3, 4, 5, 6	50
					1200	8, 9, 10, 11, 12	50
15-01	5	12.09.2022	14°33.08‘N	20°59.14‘W	4240	2, 3, 4, 5, 6	50
					350	11, 12, 13, 14, 15	50
17-01	6	14.09.2022	08°28.78‘N	19°28.04‘W	4400	2, 3, 4, 5, 6	50
					850	9, 10, 11, 12, 13	50
20-01	7	16.09.2022	00°00.0‘N	15°00.0‘W	3600	2, 3, 4, 5, 6	50
					800	9, 10, 11, 12, 13	50
25-01	8	21.09.2022	10°00.0‘S	00°00.0‘E	5500	2, 3, 4, 5, 6	50
					800	9, 10, 11, 12, 13	50
29-01	9	24.09.2022	20°15.0‘S	06°21.0‘E	800	4, 5, 6, 7	40
					10 (surface)	19, 20, 21, 22, 23, 24	60
31-01	10	26.09.2022	25°49.8‘S	09°42.0‘E	3990	2, 3, 4, 5	40
					800	8, 9, 10	30
					10 (surface)	22, 23, 24	30

Preliminary (expected) results

The goal was to constrain the role of marine emissions in the atmospheric budget of carbonyl sulfide. Analysing the isotopic fingerprint of COS and CS2 in seawater and the marine boundary layer provides information on its spatiotemporal variability, which helps to constrain the role of oceanic emissions in mass balance approaches, that currently are based on only a few data points with a large coastal impact (Davidson et al. 2021). Our measurements consitiute the first open-ocean measurements of the isotopic sulfur ratio in COS and its precursor CS2. Concentrations of COS and CO in surface seawater showed distinct diurnal cycles as expected, with considerable day-to-day variations (Fig. 4.1). Molecular DOM composition and optical properties will be measured subsequently in the lab. Overall, we expect the results to establish an oceanic isotopic fingerprint of COS emissions and help to improve mechanistic models of marine COS and CS2 cycling.

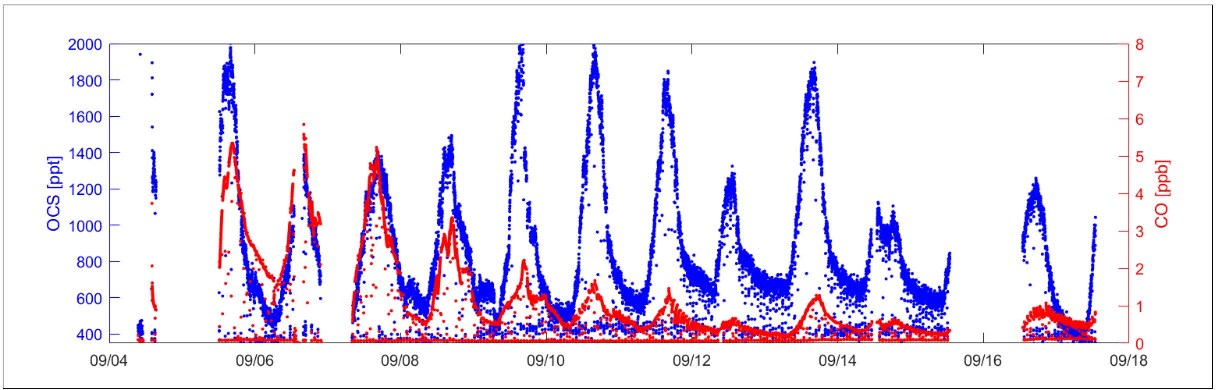

Fig. 4.1: Raw data of continuous measurements of OCS and CO in the marine boundary layer and equilibrated air in the equilibrator supplied with surface seawater

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) upon peer-reviewed publication. By default, the CC-BY license will be applied.

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

In all publications based on this expedition, the Grant No. AWI_PS132_04 will be quoted and the following publication will be cited:

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

References

Davidson C, Amrani A, Angert A (2021) Tropospheric carbonyl sulfide mass balance based on direct measurements of sulfur isotopes. Proc Natl Acad Sci U S A 118: https://doi.org/10.1073/PNAS.2020060118/SUPPL_FILE/PNAS.2020060118.SAPP.PDF.

Lennartz ST, Marandino CA, von Hobe M, et al (2017) Direct oceanic emissions unlikely to account for the missing source of atmospheric carbonyl sulfide. Atmos Chem Phys 17:385–402. https://doi.org/10.5194/acp-17-385-2017.

Pos WH, Riemer DD, Zika RG (1998) Carbonyl sulfide (OCS) and carbon monoxide (CO) in natural waters: evidence of a coupled production pathway. Mar Chem 62:89–101. https://doi.org/10.1016/S0304-4203(98)00025-5.

APPENDIX

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

A.4. STATIONSLISTE / STATION LIST

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

Affiliation	Address
DE.AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
DE.DWD	Deutscher Wetterdienst Seewetteramt Bernhard Nocht Str. 76 20359 Hamburg Germany
DE.MPIMM	Max-Planck-Institut für Marine Mikrobiologie Celisusstr.1 28359 Bremen Germany
DE.UNI-Oldenburg	Carl von Ossietzky Universität Oldenburg Institut für Chemie und Biologie des Meeres Carl-von-Ossietzky-Strasse 9-13 26132 Oldenburg Germany
IE. NUIG	National University of Ireland, Galway University Road, 91 TK33 Galway Ireland
IS.HUJI	The Hebrew University of Jerusalem Edmond J. Safra Campus - Givat Ram 9190401 Jerusalem Israel
PT.UAlg	Universidade de Algarve Campus de Gambelas 8005-139 Faro Portugal
UK. UEA	University of East Anglia Norwich Research Park NR4 7TJ United Kingdom
ZA.UCT	University of Cape Town Private Bag X3 7701 Rondebosch South Africa

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
Abdelmeneam Aboalmaati	Basma Elasaad	DE.AWI	Student	Biology
Abdulfatai	Mujeeb Akanbi	DE.AWI	Student	Oceanography
Amann	Rudolf Ignaz	DE.MPIMM	Scientist	Microbiology
Avidani	Yasmin Miya	IS.HUJI	Student	Geosciences
Baker	Alexander Roberts	UK.UEA	Scientist	Oceanography
Cabasan	Joey	DE.AWI	Student	Oceanography
Claußen	Marthe	DE.AWI	Technician	Biology
Croot	Peter	IE.NUIG	Scientist	Oceanography
Dorschel	Kolja	DE.AWI	Student	Bathymetry
Dummermuth	Angelika	DE.AWI	Scientists	Biology
Fofonova	Vera	DE:AWI	Scientist	Oceanography
Gimenez	Lucas Hernan	DE.AWI	Student	Biology
Gonzalez Rejon	Joana Julieta	DE.AWI	Student	Oceanography
Guignard	Maïté Stéphanie	DE.AWI	Scientist	Biology
James	Hannah	DE.AWI	Physiotherapist	
Krishnakumar	Hridya	DE.AWI	Student	Oceanography
Lemke	Peter	DE.AWI	Scientist	Physics
Maya	Roger	DE.AWI	Student	Oceanography
Mvula	Philile	ZA.UCT	Student	Oceanography
Nohales Coscollá	Maria	PT.UAlg	Student	Biology
Owen	Maximilian Arnold	DE.CAU	Student	Geosciences
Peters	Silivia	DE.AWI	Technician	Biology
Rohleder	Christian	DE.DWD	Technician	Meteorology
Rößler	Leonard	DE.MPIMM	Student	Biology
Schulze Tenberge	Yvonne	DE.AWI	Scientists	Bathymetry
Schwarzbach	Patrick	DE.AWI	Engineer	Bathymetry
Sidorenko	Dmitry	DE.AWI	Scientists	Oceanography
Simon	Heike	DE.UNI-Oldenburg	Technician	Chemistry
Sultana	Tania	DE.AWI	Student	Oceanography
Wiltshire	Karen Helen	DE.AWI	Scientist	Biology
Zapata Hinestroza	Jorvin Alexander	DE.AWI	Student	Oceanography
Zinzindohoué	Coffi Gérard Franck	DE.AWI	Student	Oceanography

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

No	Name	Name	Position
01	Schwarze	Stefan	Master
02	Kentges	Felix	Chiefmate
03	Grafe	Jens	Chief
04	Falk	Stefan	2nd Mate
05	Hering	Igor	2nd Mate
06	Lange	Felix	3rd Mate
07	Müller	Andreas	ELO
08	Goessmann-Lange	Petra	Shops Doc
09	Brose	Thomas Christian Gerhard	2nd. Eng
10	Beyer	Mario	2nd. Eng
11	Haack	Michael Detlev	2nd. Eng
12	Redmer	Jens Dirk	ELO
13	Jäger	Vladimir	ELO
14	Kliemann	Olaf	ELO
15	Tardeck	Frederic	ELO
16	Zohrabyan	David Rubeni	ELO
17	Sedlak	Andreas Enrico	Bosun
18	Neisner	Winfried	Carpen.
19	Frerichs	Nils	MP Rat.
20	Grünberg	Niklase	MP Rat.
21	Jassmann	Marvin	MP Rat.
22	Klee	Philipp	MP Rat.
23	Meier	Jan	MP Rat.
24	Bäcker	Andreas	AB
25	Burzan	Gerd-Ekkehard	AB
26	Wende	Uwe	AB
27	Preußner	Jörg	Storek.
28	Claasen	Thies	MP Rat.
29	Hänert	Ove	MP Rat.
30	Klinger	Dana	MP Rat.
31	Rhau	Lars-Peter	MP Rat.
32	Schwarz	Uwe	MP Rat.
33	Matter	Sebastian Udo	Cook

No	Name	Name	Position
34	Hammelmann	Louisa	Cooksm.
35	Silinski	Frank	Cooksm.
36	Pieper	Daniel	Chief Stew.
37	Wöckener	Martina	Nurse
38	Arendt	René	2nd Stew
39	Chen	Dansheng	2nd Stew.
40	Krause	Tomasz	2nd Stew
41	Silinski	Carmen	2nd Stew.
42	Sun	Yongsheng	Laundrym.

A.4 STATIONSLISTE / STATION LIST PS132

Station list of expedition PS132 from Bremerhaven to Cape Town; the list details the action log for all stations along the cruise track.

See https://www.pangaea.de/expeditions/events/PS132 to display the station (event) list for expedition PS132.
This version contains Uniform Resource Identifiers for all sensors listed under https://sensor.awi.de. See https://www.awi.de/en/about-us/service/computing-centre/data-flow-framework.html for further information about AWI's data flow framework from sensor observations to

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS132-track		2022-08-30T00:00:00	53.56750	8.55480		CT	Station start	Bremerhaven - Cape Town
PS132-track		2022-08-30T00:00:00	-33.90680	18.43370		CT	Station end	Bremerhaven - Cape Town
PS132_0_Underway-28		2022-08-30T14:00:00	53.56165	8.55974	2	SWEAS	Station start	
PS132_0_Underway-28		2022-08-30T14:00:00	-30.01722	12.54136	3597.5	SWEAS	Station end	
PS132_0_Underway-14		2022-09-01T05:00:00	51.89279	4.43562		NEUMON	Station start	
PS132_0_Underway-14		2022-09-01T05:00:00	-30.01719	12.54133	3597.5	NEUMON	Station end	
PS132_0_Underway-6		2022-09-01T06:00:00	51.89279	4.43562		MYON	Station start	
PS132_0_Underway-6		2022-09-01T06:00:00	-30.01722	12.54136	3597.5	MYON	Station end	
PS132_0_Underway-34		2022-09-01T12:30:00	52.00085	4.02641	6.6	MICA	max depth	
PS132_0_Underway-33		2022-09-02T04:30:00	50.53054	-0.03372	55.7	UWS	Station start	
PS132_0_Underway-33		2022-09-02T04:30:00	-26.76770	10.33774	4671.6	UWS	Station end	
PS132_0_Underway-13		2022-09-02T08:10:01	50.31667	-1.28352	41.9	MBES	Station start	
PS132_0_Underway-13		2022-09-02T08:10:01	-30.53944	13.05375	3313.4	MBES	Station end	
PS132_1-1		2022-09-03T06:36:15	48.48836	-7.26742	157.8		max depth	
PS132_1-2		2022-09-03T06:43:00	48.48320	-7.28040	158.6	BUCKET	max depth	
PS132_0_Underway-32		2022-09-03T12:00:00	47.98448	-8.52499	985	FBOX	Station start	

** Comments are limited to 130 characters. See https://www.pangaea.de/expeditions/events/PS132 to show full comments in conjunction with the station (event) list for expedition PS132*

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS132_0_Underway-32		2022-09-03T12:00:00	-30.01722	12.54136	3597.5	FBOX	Station end	
PS132_0_Underway-17		2022-09-03T12:10:00	47.96803	-8.56577	1351.4	pCO2	Station start	
PS132_0_Underway-17		2022-09-03T12:10:00	-30.01722	12.54136	3597.5	pCO2	Station end	
PS132_0_Underway-12		2022-09-03T12:15:00	47.95984	-8.58602	1557.9	GRAV	Station start	
PS132_0_Underway-12		2022-09-03T12:15:00	-30.01722	12.54136	3597.5	GRAV	Station end	
PS132_0_Underway-1		2022-09-03T12:30:00	47.93832	-8.63940	1682.6	ADCP	Station start	
PS132_0_Underway-1		2022-09-03T12:30:00	-30.01722	12.54136	3597.5	ADCP	Station end	
PS132_2-1		2022-09-03T13:34:51	47.92983	-8.65910	2023.6	CTD-RO	max depth	
PS132_2-2		2022-09-03T14:34:42	47.92937	-8.65776	2048.8	FLU	Station start	Fluorometer with Plankton-Net
PS132_2-2		2022-09-03T14:34:42	47.92883	-8.65703	2085.7	FLU	Station end	Fluorometer with Plankton-Net
PS132_3-1		2022-09-04T05:40:36	45.45012	-10.21001	3515.3		max depth	
PS132_3-2		2022-09-04T05:50:14	45.43602	-10.22021	3716.4	BUCKET	max depth	
PS132_4-1		2022-09-04T20:25:55	43.49985	-11.62776	5033.5	CTD-RO	max depth	
PS132_5-1		2022-09-05T04:01:39	42.55644	-11.85177	1044		max depth	
PS132_5-2		2022-09-05T04:17:12	42.53284	-11.85805	1169.2	BUCKET	max depth	
PS132_6-1		2022-09-06T04:26:26	38.43149	-13.11399	4600.3		max depth	
PS132_6-2		2022-09-06T04:33:45	38.42042	-13.11681	4609.6	BUCKET	max depth	
PS132_7-1		2022-09-06T23:24:57	35.50025	-13.85452	4837.4	CTD-RO	max depth	
PS132_7-2		2022-09-07T01:13:27	35.49985	-13.85538	4835.4	FLU	Station start	with Plankton-Net
PS132_7-2		2022-09-07T01:13:27	35.49865	-13.85598	4831.4	FLU	Station end	with Plankton-Net
PS132_8-1		2022-09-07T03:43:27	35.19723	-13.99790	4277		max depth	
PS132_8-2		2022-09-07T03:50:32	35.18633	-14.00010	4287.7	BUCKET	max depth	
PS132_9-1		2022-09-08T04:35:45	31.07239	-14.85643	3901.3		max depth	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS132_9-2		2022-09-08T04:43:14	31.06278	-14.85974	3888.2	BUCKET	max depth	
PS132_10-1		2022-09-08T12:17:01	30.00001	-14.99990	3290.3	CTD-RO	max depth	
PS132_11-1		2022-09-09T21:05:38	25.32247	-18.08292	3128.5		max depth	
PS132_11-2		2022-09-09T21:12:26	25.31630	-18.08844		BUCKET	max depth	
PS132_12-1		2022-09-10T16:01:44	22.50171	-20.58180			max depth	
PS132_12-2		2022-09-10T16:17:16	22.49812	-20.58548		BUCKET	max depth	
PS132_12-3		2022-09-10T16:19:02	22.49980	-20.58434		FLOAT	Station start	
PS132_12-3		2022-09-10T16:19:02	22.49832	-20.58549		FLOAT	Station end	
PS132_13-1		2022-09-11T12:39:02	18.29908	-20.82320			max depth	
PS132_13-2		2022-09-11T12:46:15	18.28876	-20.82283		BUCKET	max depth	
PS132_14-1		2022-09-12T08:41:10	14.59236	-20.96695			max depth	
PS132_14-2		2022-09-12T08:48:20	14.58416	-20.97202		BUCKET	max depth	
PS132_15-1		2022-09-12T10:42:30	14.56108	-20.98928		CTD-RO	max depth	
PS132_15-2		2022-09-12T12:19:00	14.56525	-20.99046		FLU	Station start	
PS132_15-2		2022-09-12T12:19:00	14.56706	-20.99446		FLU	Station end	
PS132_16-1		2022-09-13T21:18:53	10.61692	-20.12645			max depth	
PS132_16-2		2022-09-13T21:26:41	10.60845	-20.12915		BUCKET	max depth	
PS132_17-1		2022-09-14T12:29:59	8.47980	-19.46799		CTD-RO	max depth	
PS132_17-2		2022-09-14T14:10:18	8.47935	-19.46780		FLU	Station start	
PS132_17-2		2022-09-14T14:10:18	8.47743	-19.46660		FLU	Station end	
PS132_18-1		2022-09-14T21:22:17	7.59302	-18.79769			max depth	
PS132_18-2		2022-09-14T21:30:22	7.58365	-18.79052		BUCKET	max depth	
PS132_19-1		2022-09-16T04:12:47	2.80098	-16.45042			max depth	
PS132_19-2		2022-09-16T04:21:27	2.79154	-16.44561		BUCKET	max depth	
PS132_20-1		2022-09-17T00:26:51	-0.00066	-14.99990		CTD-RO	max depth	
PS132_20-2		2022-09-17T01:54:04	-0.00023	-14.99860		FLU	Station start	
PS132_20-2		2022-09-17T01:54:04	0.00006	-14.99250		FLU	Station end	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS132_21-1		2022-09-17T04:56:24	-0.21392	-14.62960			max depth	
PS132_21-2		2022-09-17T05:04:00	-0.21960	-14.62160		BUCKET	max depth	
PS132_22-1		2022-09-18T06:13:37	-2.73653	-11.09665			max depth	
PS132_22-2		2022-09-18T06:20:42	-2.74133	-11.08887		BUCKET	max depth	
PS132_23-1		2022-09-19T06:50:53	-4.89049	-7.43530			max depth	
PS132_23-2		2022-09-19T06:57:38	-4.89544	-7.42791		BUCKET	max depth	
PS132_24-1		2022-09-21T03:39:31	-9.25953	-1.00046			max depth	
PS132_24-2		2022-09-21T03:48:00	-9.26537	-0.99248		BUCKET	max depth	
PS132_25-1		2022-09-21T12:49:00	-9.99991	0.00014		CTD-RO	max depth	
PS132_25-2		2022-09-21T14:53:00	-9.99972	-0.00015		FLU	Station start	
PS132_25-2		2022-09-21T14:53:00	-9.99985	0.00000		FLU	Station end	
PS132_25-3		2022-09-21T15:22:33	-9.99979	0.00000		FLOAT	Station start	
PS132_25-3		2022-09-21T15:22:33	-9.99960	0.00000		FLOAT	Station end	
PS132_26-1		2022-09-22T05:07:58	-11.98905	1.27235			max depth	
PS132_26-2		2022-09-22T05:16:17	-11.99804	1.27786		BUCKET	max depth	
PS132_27-1		2022-09-23T06:06:10	-15.66399	3.54349			max depth	
PS132_27-2		2022-09-23T06:13:02	-15.67071	3.54750		BUCKET	max depth	
PS132_28-1		2022-09-24T07:56:02	-19.39089	5.68755		BUCKET	max depth	
PS132_29-1		2022-09-24T15:47:35	-20.25093	6.34953		CTD-RO	max depth	
PS132_29-2		2022-09-24T17:35:06	-20.25089	6.35029		FLU	Station start	
PS132_29-2		2022-09-24T17:35:06	-20.25122	6.35036		FLU	Station end	
PS132_29-3		2022-09-24T18:04:24	-20.25111	6.35036		FLOAT	Station start	
PS132_29-3		2022-09-24T18:04:24	-20.25162	6.35061		FLOAT	Station end	
PS132_30-1		2022-09-25T06:27:15	-22.10420	7.45386			max depth	
PS132_30-2		2022-09-25T06:30:01	-22.10710	7.45559		BUCKET	max depth	
PS132_31-1		2022-09-26T06:48:05	-25.83006	9.70088		CTD-RO	max depth	
PS132_31-2		2022-09-26T08:30:55	-25.83020	9.70044		FLU	Station start	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS132_31-2		2022-09-26T08:30:55	-25.82991	9.70093		FLU	Station end	
PS132_32-1		2022-09-27T08:20:23	-29.25766	12.05829		CTD-UW	Station start	
PS132_32-1		2022-09-27T08:20:23	-29.26729	12.06546		CTD-UW	Station end	
PS132_32-2		2022-09-27T08:28:15	-29.26795	12.06601		BUCKET	max depth	
PS132_33-1		2022-09-27T11:30:27	-29.47513	12.22437		CTD-RO	max depth	

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Abbreviation	Method/Device
ADCP	Acoustic Doppler Current Profiler
BUCKET	Bucket water sampling
CT	Underway cruise track measurements
CTD-RO	CTD/Rosette
CTD-UW	CTD, underway
FBOX	FerryBox
FLOAT	Floater
FLU	Fluorometer
GRAV	Gravimetry
MBES	Multibeam echosounder
MICA	Mid-Infrared CAvity enhanced spectrometer
MYON	DESY Myon Detector
NEUMON	Neutron monitor
SWEAS	Ship Weather Station
UWS	Underway water sampling
pCO2	pCO2 sensor
XBT	eXpendable BathyThermograph

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