METEOR-Berichte

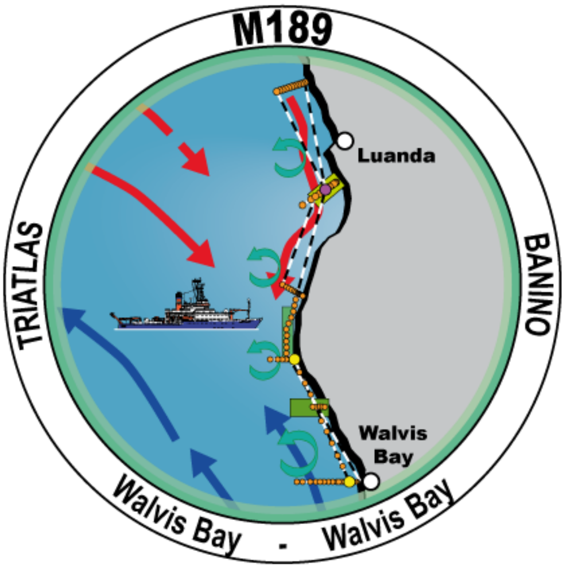
Benguela Niños: Physical Processes in Upwelling Regions and Long-Term Variability

Cruise No. M189/1

April 16 – May 13, 2023

Walvis Bay (Namibia) – Walvis Bay (Namibia)

BANINO



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2024

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1 Cruise Summary

1.1 Summary in English

During FS METEOR cruise M189/1, a physical-biogeochemical study was carried out in the coastal upwelling area of the south-eastern Atlantic off Angola and Namibia. The measurement program was an integral component of the BMBF-collaborative research project “Benguela Niños: Physical processes and long-term variability (BANINO)”. The major goals of the cruise were to (1) maintain and enhance the ocean observing system off southwest Africa to assess the variability of the eastern boundary circulation and upwelling on time scales from subseasonal to decadal; (2) investigate physical and biogeochemical processes responsible for the variability of upwelling, biological productivity and trace gas emission. The work program included the successful recovery and redeployment of long-term current meter moorings and a sediment trap off Angola and Namibia, deployment and recovery of autonomous observatories and hydrographic measurements along several section carried out in combination with ocean turbulence measurements and water sampling. Water samples were analysed for solute concentrations including oxygen, nutrients, trace gases, sulphur, salinity, primary productivity, microbial gene abundances and single cell activity. Trace gas concentrations, temperature, salinity in the surface waters and ocean currents in the upper water column were continuously monitored throughout the cruise.

1.2 Zusammenfassung

Auf der FS METEOR Fahrt M189/1 wurden eine physikalisch-biogeochemische Studie im Küstenauftriebsgebiet des südöstlichen Atlantiks vor Angola und Namibia durchgeführt. Das Messprogramm war integraler Bestandteil des BMBF-Verbundvorhabens "Benguela Niños: Physikalische Prozesse und Langzeitvariabilität (BANINO)". Die Hauptziele der Fahrt waren (1) die Wartung und Ergänzung des Ozeanbeobachtungssystems vor Südwestafrika zur Erfassung der Variabilität der östlichen Randzirkulation und des Auftriebs auf Zeitskalen von sub-saisonal bis dekadisch; (2) Untersuchungen der physikalischen und biogeochemischen Prozesse, die für die Variabilität des Auftriebs, der biologischen Produktivität und der Spurengasemissionen verantwortlich sind. Das Arbeitsprogramm umfasste die erfolgreiche Bergung und Wiederausbringung von Langzeitströmungsverankerungen und einer Sedimentfalle vor Angola und Namibia, die Ausbringung und Bergung autonomer Observatorien und hydrographische Messungen entlang mehrerer Schnitte, die in Kombination mit Ozeanturbulenzmessungen und Wasserprobenentnahme durchgeführt wurden. Die Wasserproben wurden auf die Konzentrationen gelöster Stoffe, einschließlich Sauerstoff, Nährstoffe, Spurengase, Schwefel, Salzgehalt, Primärproduktion, mikrobielle Genhäufigkeit und Einzelzellaktivität untersucht. Die Konzentrationen von Spurengasen, Temperatur, und Salzgehalt im Oberflächenwasser und die Meeresströmungen in der oberen Wassersäule wurden während der gesamten Fahrt kontinuierlich aufgenommen.

2 Participants

2.1 Principal Investigators

Name	Institution
Dengler, Marcus, Dr.	GEOMAR
Arévalo-Martínez, Damian L., Dr.	RU
Mohrholz, Volker, Dr.	IOW

2.2 Scientific Party

Name	Discipline	Institution
Arévalo Martínez, Damian L., Dr.	CO, trace gases, nutrients, sulfur	RU
Aroucha, Léo Costa	PO, CTD, thermosalinograph	GEOMAR
Awo, Founi Mesmin, Dr.	PO, CTD, thermosalinograph	UCT
Begler, Christian	PO, moorings, glider, MVP	GEOMAR
Dengler, Marcus, Dr.	PO, chief scientist	GEOMAR
Eisnecker, Paula	CO, trace gases, nutrients, sulfur	GEOMAR
Elsässer, Antje	ME, weather station, forecast	DWD
Friedrich, Berit	PO, CTD, salinometer	GEOMAR
Henning, Philipp	PO, CTD, moorings, microstructure	GEOMAR
Imbol Kongue, Rodrigue A., Dr.	PO, CTD, moorings, VMADCP	GEOMAR
Jacobsen, Mats	BO, productivity, POM, DIC	SDU
Körner, Mareike	PO, CTD, VMADCP, microstructure	GEOMAR
Krahmann, Gerd, Dr.	PO, CTD, glider, moorings	GEOMAR
Melzer, Hannah	PO, CTD, satellite retrievals	GEOMAR
Mock, Leon	PO, CTD, oxygen titration, nutrients	GEOMAR
Mrozowska, Marta A.	PO, CTD, surface drifter	NBI
Nielsen, Martina	PO, moorings, logistics	GEOMAR
Otte, Frank	ME, weather station, forecast	DWD
Perschon, Justus	PO, CTD, salinometer	GEOMAR
Pöhnl, Denise	PO, CTD, oxygen titration	GEOMAR
Reese, Nina	POM, CTD, MVP	IOW
Söder, Jens, Dr.	POM, moorings, microstructure	IOW
Stockmayer, Vera	PO, CTD, surface fluxes	GEOMAR
Wölker, Yannick	PO, CTD, surface drifter	GEOMAR

PO: Physical Oceanography, CO: Chemical Oceanography, BO: Biological Oceanography, ME: Meteorology

2.3 Participating Institutions

GEOMAR	Helmholtz-Zentrum für Ozeanforschung Kiel, Germany
DWD	Deutscher Wetterdienst, Geschäftsfeld Seeschifffahrt, Germany
IOW	Leibniz-Institut für Ostseeforschung Warnemünde, Germany
NBI	Niels Bohr Institute, Copenhagen, Denmark

RU	Radboud Universiteit, Nijmegen, Netherlands
SDU	University of Southern Denmark, Odense, Denmark
UCT	University of Cape Town, Rondebosch, South Africa

3 Research Program

3.1 Description of the Work Area

The R/V METEOR cruise M189/1 was carried out in the central and northern region of the Benguela Current Large Marine Ecosystem (BCLME) that extend from the Congo River mouth to the southern tip of Africa. The BCLME can be separated in three different subsystems: the tropical Angolan Upwelling System (tAUS, 6°S - 17°S), the northern Benguela Upwelling System (nBUS, 17°S - 27°S), and the southern Benguela Upwelling System (sBUS, 27°S - 35°S) that can roughly be associated with the three coastal countries, Angola, Namibia and South Africa, respectively (Fig. 3.1, Jarre et al., 2015). South-easterly trade winds prevail in the south-eastern Atlantic that predominately follow the direction of the coastline (Fig. 3.1 b).

In combination with the strengthening of the winds away from the coasts, along-shore winds are a primary physical driver of the upwelling of cold and nutrient-rich waters along the coast sustaining elevated productivity at the continental margin (Fig. 3.1 b, Bordbar et al., 2021). The strongest alongshore winds are found in the northern Benguela Upwelling System off the Namibian coast and are associated with the atmospheric Benguela Low Level Coastal Jet (Patricola and Chang, 2017). In the tropical Angolan Upwelling System, winds are substantially weaker with marginal seasonal variations marked by slightly enhanced southerly winds in austral spring and calm winds in austral winter (Brandt et al., 2024, Körner et al., 2024).

The wind-driven ocean circulation in the BCLME is characterized by mostly meridional currents along the eastern boundary of the South Atlantic (Fig. 3.1 a). The equatorward extension of the Guinea Current (GC) and the Guinea Undercurrent as well as the Equatorial Undercurrent (EUC) supply low-oxygen but saline South Atlantic Central Water (SACW, Fig. 3.1 c) to the southward Gabon-Congo Undercurrent (GCUC) (Wacongne and Piton, 1992). South of about 5°S, the poleward flow of SACW continues as the Angola Current (AC) in the tAUS (Tchipalanga et al., 2016; Kopte et al., 2017) and eventually as the Poleward Undercurrent (PUC) through the nBUS into the sBUS (Mohrholz et al., 2008, Nelson, 1989). Additionally, low-oxygen SACW is carried toward the east and the south by the South Equatorial Undercurrent (SEUC) and by the South Equatorial Countercurrent (SECC) (Siegfried et al., 2019). Along the eastern boundary, the poleward flowing SACW meets the colder and fresher Eastern SACW (ESACW) flowing northward within the Benguela Current. The confluence of these two currents at about 17°S causes an elevated meridional sea surface temperature (SST) gradient that is termed the Angola-Benguela Frontal Zone (ABFZ) (Fig. 3.1 a). The Benguela Current can be described as being composed of an offshore branch (Benguela Offshore Current, BOC) and a coastal branch (Benguela Coastal Current, BCC) (Siegfried et al., 2019). After converging in the ABFZ, the eastern boundary flow turns westward, forming - together with the BOC - the southern branch of the SEC (sSEC) that constitutes the main westward branch of the South Atlantic subtropical gyre.

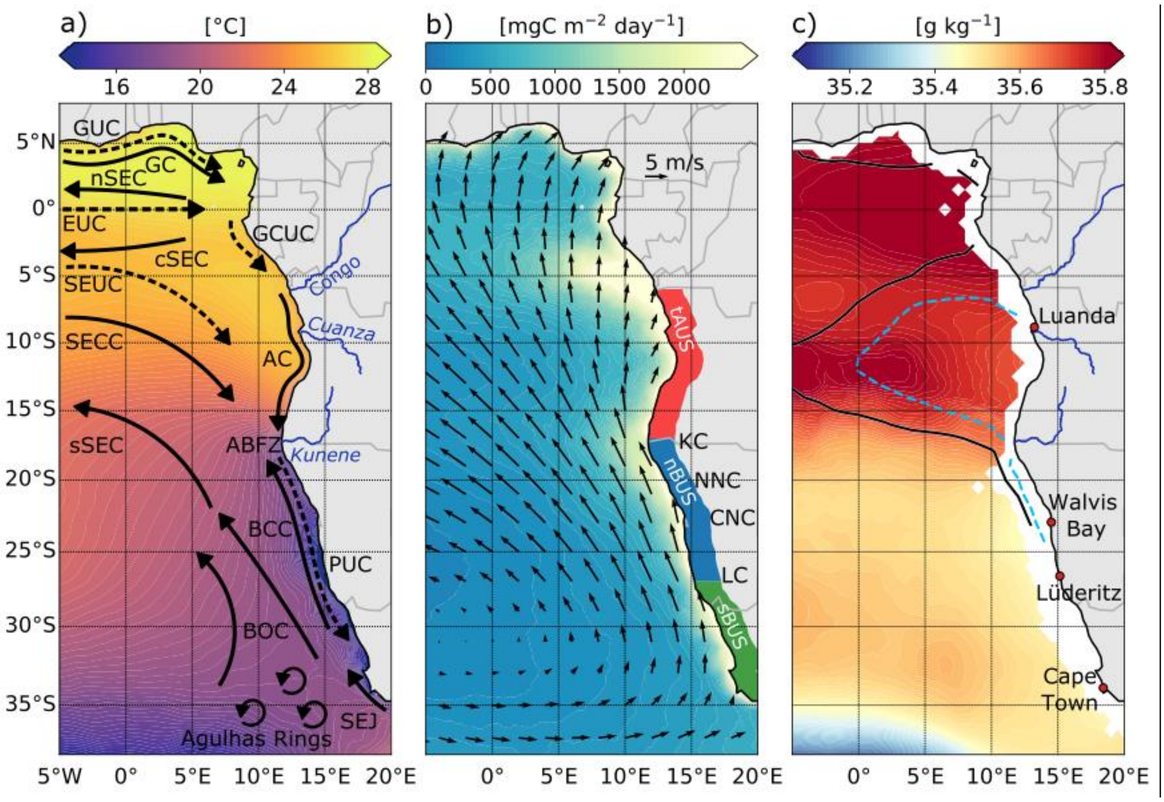

Fig. 3.1 Mean background conditions and circulation schematic for the eastern boundary upwelling system of the South Atlantic. (a) Sea surface temperature in the eastern tropical and subtropical South Atlantic with circulation schematic superimposed, (b) net primary production as deduced from satellite observations with surface wind vectors superimposed, and (c) absolute salinity on the potential density surface 26.3 kg m^{-3}. In (a), surface (solid arrows) and thermocline (dashed arrows) current branches shown are the Guinea Undercurrent (GUC), the Guinea Current (GC), the Equatorial Undercurrent (EUC), the northern, central and southern branches of the South Equatorial Current (nSEC, cSEC, and sSEC), the South Equatorial Undercurrent (SEUC), the South Equatorial Countercurrent (SECC), the Gabun-Congo Undercurrent (GCUC), the Angola Current (AC), the Poleward Undercurrent (PUC), the Benguela Offshore and Coastal Currents (BOC and BCC), and the shelf-edge jet (SEJ). Also marked in (a) is the Angola-Benguela Frontal Zone (ABFZ) at about 17°S and the three rivers Congo, Cuanza, and Kunene. In (b) the latitude range of the three subregions, the tropical Angolan and the northern and southern Benguela upwelling systems (tAUS, nBUS, sBUS) as well as mean latitudes of the dominant upwelling cells, the Kunene cell, the Northern Namibian cell, the Central Namibian cell, and the Lüderitz cell (KC, NNC, CNC, LC) are marked. In (c), the 70 µmol kg^{-1} oxygen concentration contours at 130 m depth (light blue dashed line) and at 250 m depth (black line) are included (from Brandt et. al., 2024).

Among the eastern boundary upwelling systems, the BCLME has the highest primary production rates (Messié et al., 2009). Elevated oxygen consumption due to the degradation of organic matter further reduces oxygen concentrations of the SACW as it moves poleward along the eastern boundary, leading to occasional anoxic and anoxic-sulfidic conditions in the thermocline (Mohrholz et al., 2008, Ohde and Dadou, 2018). These conditions favor elevated production of trace gases such as N_2O. Previous observations showed enhanced sea-to-air fluxes of N_2O in association with local upwelling cells in the nBUS (Arévalo-Martínez et al., 2018).

3.2 Aims of the Cruise

The objective of the physical - biogeochemical measurement program during R/V METEOR cruise M189/1 was to measure the variability of the circulation and the coastal upwelling off Angola and Namibia and elucidate the processes relevant to coastal upwelling, greenhouse gas production and emission, and biological productivity. Projects related to the cruise are the BMBF collaborative project "Benguela Niños: Physical processes and long-period variability (BANINO)" and the EU collaborative project "Tropical and South Atlantic climate-based marine ecosystem predictions for sustainable management (TRIATLAS)". Within BANINO the ocean observing system off the coast of Southwest Africa is extended to measure and understand the variability of coastal upwelling on time scales from weeks to decades. In TRIATLAS, we are studying the current state of the ecosystem in the Southern and tropical Atlantic to better predict future changes.

The aims of the cruise were to

i. continue, based on previous programs, enhancing the ocean observing system off Southwest Africa aimed at studying the eastern boundary upwelling variability on time scales from subseasonal to decadal;
ii. investigate so far not well understood processes relevant for upwelling variability and its consequences for biological productivity, such as the interaction of along-coastal winds and wind curl, coastal trapped waves, tidally generated internal waves and induced mixing on the shelf, riverine freshwater input and precipitation and frontal dynamics at the Angola Benguela frontal zone;
iii. synthesize high-resolution simulations, remote sensing of sea surface height, temperature, salinity, and chlorophyll, and in-situ observations to understand the exchange between boundary regions and the interior ocean and to understand the role of stratification within the boundary current region on the development of Benguela Niño events;
iv. investigate the impact of the changing southeastern tropical Atlantic Ocean mean state in its detailed structure on feedback processes (e.g., land-see pressure differences and coastal jets) and on Benguela Niño events with respect to their frequency, strength, location and impacts as well as their predictability;
v. resolve the microbial nitrogen and sulfur cycles in order to constrain the variability of nitrogen and sulfur turnover in the Benguela upwelling system by identifying the diversity, the metabolic potential and the identity of key active microbes involved in the respective processes particularly with regard to nitrous oxide (N_2O) formation, sulfate reduction, and dinitrogen fixation;
vi. further develop the cooperation between German and African partner institutions by enhancing the local capabilities in ocean observing, modeling and data analysis.

3.3 Agenda of the Cruise

The work program included servicing of moorings, hydrographic and velocity sections, upwelling process studies with high-resolution sampling of hydrography, turbulence, biogeochemical parameters and autonomous measurements by ocean gliders (Fig. 3.2). Additionally, continuous sampling of velocity in the upper water column and trace gas concentrations, temperature and salinity in the surface waters was carried out. Long-term oceanographic moorings measuring the variability of the eastern boundary circulation and hydrography at 11°S and at 23°S in a water depth of 1500m and 100m, respectively, were serviced and reinstalled at the same position.

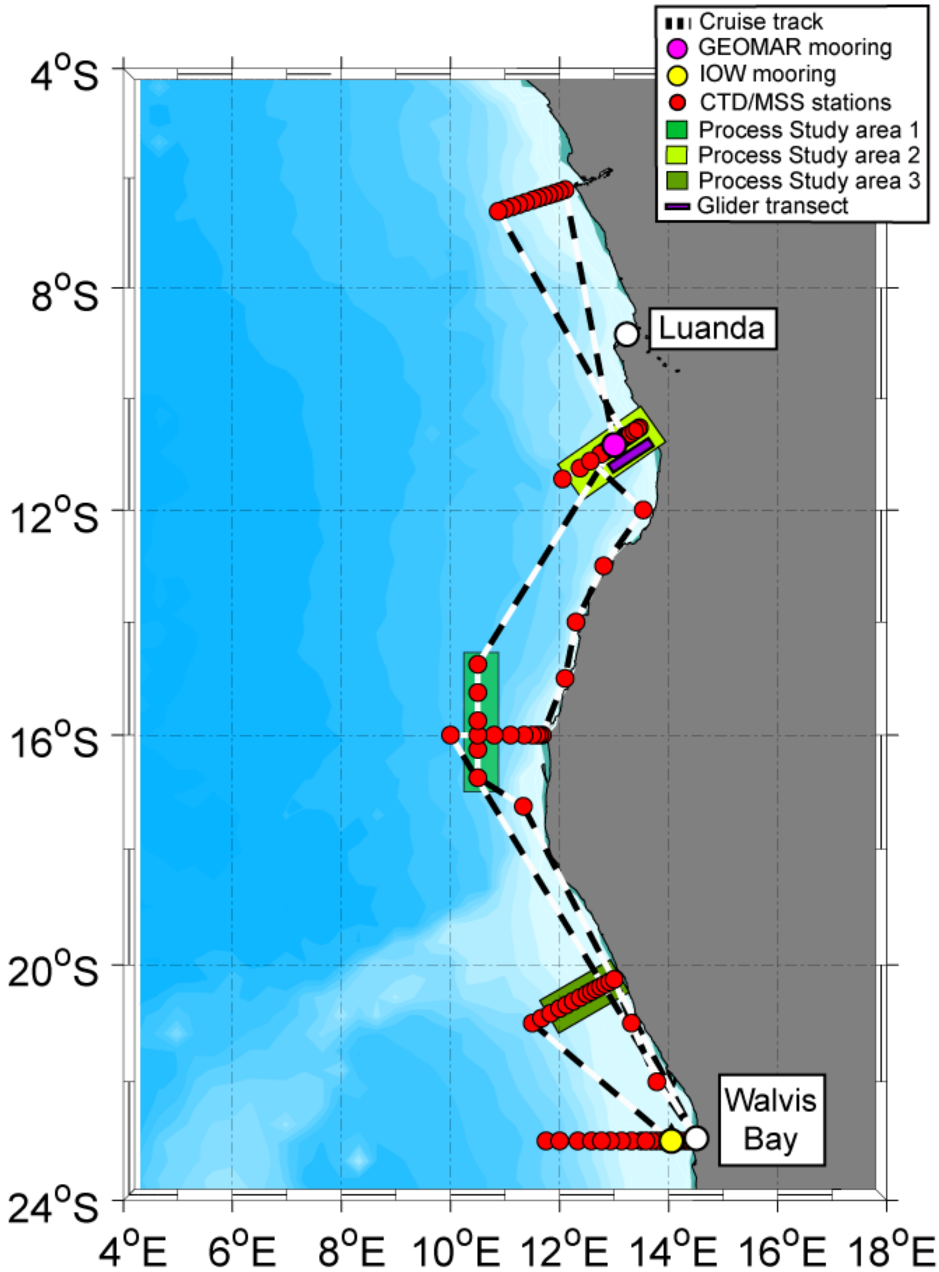

Fig. 3.2 Bathymetric map with cruise track of R/V METEOR cruise M189 (dashed black and white line) including locations of CTD/MSS stations, mooring recoveries and redeployments, and glider transects. Regions in which process studies were carried out are also marked.

Hydrographic sections (CTD/O_2) and water samples were taken along 5 predominately zonal sections at 6°S, 11°S, 16°S, 20°S and 23°S (Fig. 3.2) and along one meridional section cutting through a mesoscale cyclonic eddy in the Angola-Benguela frontal region at 10.5°E. Parameters measured by sensors attached to the CTD-rosette include temperature, salinity, pressure, chlorophyll, turbidity, nitrate and particle detection using an underwater vision profiler. All CTD/O_2 stations were accompanied by microstructure measurements to sample the strength of ocean turbulence in the upper water column.

Water samples were taken for the analysis of a variety of parameters including salinity, oxygen, nutrients (NH^{4+}, NO^{3-}, NO^{2-}, PO_3^{4-}, SiO_2), trace gases (N_2O), Sulfur (SO_3), microbial abundances and single cell activity. A 4-day-long upwelling process study was carried out at 11°S. For this experiment, short-term moorings measuring velocity and hydrography were installed along a section perpendicular to bathymetry and three ocean gliders were deployed sampling hydrography, turbidity, oxygen and chlorophyll. Additionally, the gliders were carrying sensor packages to sample nitrate, turbulence and particles using an underwater vision profiler. Repeated high-resolution profiles of turbulence and hydrography across the continental slope and shelf were taken along this section. Process studies were also carried out at 20°S, where an 18-hour microstructure station was taken at about 200m water depth, and along 10.5°E where high-resolution hydrography using a moving vessel profiler was collected while surveying through a mesoscale eddy.

The cruise was carried out in accordance with the declarations on responsible marine research (Appendices 1 to 3 of the GPF Cruise Proposal Preparation Instructions). In particular, unnecessary hydroacoustic sources with pulsed sound emissions was limited to multibeam echosounder and acoustic Doppler current profiling that were strictly necessary for scientific purposes. All other hydroacoustic pulsed instruments, such as Parasound and Posidonia remained unused during the cruise.

4 Narrative of the Cruise

With little delay, R/V METEOR left the harbor of Walvis Bay, Namibia in sunny weather under pilotage and tug assistance in the morning of April 16 and set out for the working area of Namibia. The original plan was to start research in Angolan waters. Although a research permit for Angola had been received, an additional exemption of import tax was requested, for the processing of which at least five working days have to be calculated. Without this exemption we were not allowed to enter Angolan waters. Instead, we started our work program by deploying a surface drifter having acoustic Doppler current profiler attached at 50m depth off the Namibian coast at 23°S six hours after departure. In the following days, 22 conductivity-temperature-depth (CTD) stations were occupied along the 23°S section that were mostly followed by microstructure stations (MSS) where profiles of ocean turbulence were collected. Additionally, a long-term mooring measuring ocean currents and hydrography and a sediment trap was successfully recovered and redeployed in a water depth of 135m at 23°S. The surface drifter was recovered and the 23°S section was completed three and a half days later on April 19, 22:30 UTC.

After about 18 hours of steaming, measurements along a section perpendicular to the coast at 20°S were taken. The section works here began again with the deployment of a surface drifter at a water depth of 200m in the afternoon of April 20. Altogether, 14 CTD stations were taken along the 20°S section. Unfortunately, the microstructure profiler system malfunction at the beginning of the section work. It took 9 hours to re-terminate the MSS cable and to replace the microstructure winch on the gunwale at the vessel’s stern. The MSS data collected at the CTD stations inshore of the 200m were thus not collected right after the CTD stations but during a later period. After completing the 20°S section, a process study on diapycnal mixing by non-linear internal waves was conducted by taking an 18-hour MSS time series station in the vicinity of the drifter position. The drifter was recovered in the early afternoon on April 23. Three CTD stations at shallow depth between 21°S and 23°S completed our work in Namibian waters.

R/V METEOR return to the harbor of Walvis Bay to clear customs and immigration at 9 am local time on April 24. Additionally, we received scientific instruments to measure surface trace gas concentrations that were sent by air freight from Nijmegen, Netherlands but did not make it to Walvis Bay prior to our first departure. After leaving port in the early evening, sampling with underway instrumentation was not possible before leaving Namibian territorial waters. In the morning of April 26, two hours before entering Angolan territorial waters, the requested exemption from the temporary import and export tax for R/V METEOR was granted by the Angolan General Tax Administration (AGT). Fortunately, it was not limited to 10 days as we had feared.

This allowed the continuation of our measurement program in Angolan waters. With wind and waves from astern, R/V METEOR changed course to sample the currents and stratification in the Angola-Benguela Frontal Zone on a meridional section along 10.5°E. This section cut through a cyclonic mesoscale eddy that had developed in the Angola-Benguela front in mid-March. The section was completed on Thursday afternoon, April 27 and we set course for the coastal region off Angola at 11°S. The elevated water and air temperatures and the decreasing winds north of 15°S led to an abrupt change of clothing of all cruise participants and a busy working deck. In the evening, we celebrated the mid-cruise festival with a barbecue on deck.

The main study area in Angolan waters at 11°S was reached on Friday afternoon, April 28. CTD and MSS measurements were taken along a section perpendicular to the coast during the night. In the next morning on April 29, two landers equipped with acoustic Doppler velocity profilers and a mooring were deployed along the upper continental slope and shelf at 11°S, slightly south of our main CTD section at 11°S. Additionally, three gliders with different auxiliary sensors were released at the upper continental slope and 12 surface drifters with shallow drogues (Hereon drifter) were deployed in water depth shallower than 450m. The short-term moorings and the gliders were deployed for nearly 10 days to sample the physical and biogeochemical processes associated with coastal upwelling in tropical Angolan upwelling region. CTD and MSS stations along the 11°S were continued for the rest of the day until we headed north just after midnight to take a section at 6°S. CTD and MSS sampling along the 6°S section was started in the morning of May 1 and completed 25 hours later. Hydrographic data using the Moving Vessel Profiler (MVP) was collected while returning to the 11°S section. Unfortunately, the cable of the MVP broke after 9 hours of sampling leading to a termination of MVP measurements.

CTD and MSS sampling along the 11°S section was continued starting in the afternoon of May 3. The long-term mooring KPO 1246 deployed at a water depth of 1200m to record the variability of the boundary current circulation in the tropical Angolan upwelling region (Fig. 1), which has been maintained for almost 10 years by GEOMAR in collaboration with the Instituto Nacional de Investigação Pesqueira in Luanda, was recovered in the afternoon of May 4. After the mooring recovery, glider ifm14 was retrieved. The lamp of the Underwater Vision Profiler that was attached to a glider for the first time during a see-going experiment, had become loose. The glider was not redeployed. We completed the 11°S section three hour later at 21:00 UTC.

The upwelling process study at 11°S was started with a high resolution MSS transect from a water depth of 450m to 50m. Altogether, 107 profiles were collected until the next morning. After recovering a drifter, MSS data were collected from the rubber boat in very shallow waters (~25m water depth). In the evening of May 5, an MVP section from a water depth of 50m to 450m along the 11°S section was started. At about 20:00 UTC, we noticed that glider ifm13 had not surfaced at the predicted position, but about 8 nautical miles to the southeast. The station work was discontinued and R/V METEOR headed for the last known position of the glider. At first, our search was unsuccessful, we could neither find an AIS signal, nor small fishing boats by means of ship radar in the area. Renewed position reports of the glider shortly after midnight indicated that it was already in the roadstead off the town of Porto Amboim, about 10 nautical miles south of the 11°S section. After continuing the MVP section work until the morning of May 6, the position of the glider was visited first with R/V METEOR and later with the rubber boat. Thanks to the very accurate GPS information, we were able to quickly locate the fishing boat, about 8 m long, among the many boats anchoring there. The fishermen were very cooperative and both sides were very happy about an exchange deal in which we got back our intact instrument for ship's paint, oilskins, sunglasses and some supplies from the store of the first steward. In the afternoon, as a precautionary measure, the remaining glider ifm09 was retrieved and the long-term mooring (KPO 1272) was redeployed at 1200m water depth. Over the night until the next morning, further turbulence measurements were carried out in shallow waters along the 11°S section, which completed the process study at 11°S.

In the morning of May 7, the two lander and the short-term mooring were recovered and R/V METEOR took course to 16°S. On the way, CTD profiles were taken along the 100m isobath. The zonal section along 16°S was started on May 9 at 4:00 UTC. Altogether, 10 CTD profiles were collected along the section. Additionally, an MSS station was sampled in the evening of May 9, during which different MSS protection cages were used to test their impact on the system's noise level. The section was completed in the morning of May 10. As the meteorologist on board were forecasting elevated winds, we decided for an early arrival in the harbor and thus headed towards Walvis Bay. While steaming in southern direction, wind and swell gradually increase, peaking at 5 to 6 Bft., gusting to 7 Bft., and 3.5 m of significant swell as we enter the harbor on May 12, 11:00 UTC.

5 Preliminary Results

5.1 Hydrographic Observations

5.1.1 CTD System, Oxygen Measurements, and Calibration

(G. Krahmann, B. Friedrich, D. Pöhnl, J. Perschon, L. Mock)

During M189, a total of 94 CTD-profiles and 2247 water samples were collected. GEOMAR's Seabird SBE9 rosette system SBE-6 was installed in a Seabird Rosette System frame for 24 bottles (ROS-1). Most casts were made with all 24 bottles installed, except casts made for the calibration of MicroCATs and Optodes. Depth profiles up to a maximum pressure of 3663 dbar were performed. For the majority of stations, the full water column was sampled. Data acquisition was done using Seabird Seasave software version 7.26.7. Preprocessing was done with SBE Data Processing 7.26.7.

During instrument assembly and preparation, it was discovered the GEOMAR's Valeport altimeter had a broken pin in its connector. A Benthos altimeter was borrowed from R/V METEOR's CTD system and successfully connected. A Seabird Satlantic SUNA nitrate sensor was attached to the rosette during most of the CTD profiles. Because of its pressure rating of 2000 dbar it was removed for deep stations. After about CTD station 50 SUNA #345 started to develop problems. Its internal systems reported lamp errors and shut down sampling. This got progressively worse until it shut down after only a few seconds. SUNA #345 was removed from the CTD after CTD station 59. Upon recovery of glider Ifm13 SUNA #761 became available and was installed on the CTD for profiles 79 to 88. Profiles 89 to 94 were again deep profiles without SUNA. An Underwater Vision Profiler (UVP) was attached to the CTD frame during all profiles.

The first CTD profile was collected only a few hours after leaving the port. It was determined that all regular sensors (P,T,S,O) recorded data with sufficient accuracy. However, the secondary oxygen sensor quickly developed an unusual behavior with noisy data near the surface and seemingly good data below about 200 m depth. Exchanging the cables did not solve the problem and after CTD profile 40 the secondary oxygen sensor was exchanged for a spare one. The Chl-fluorescence and turbidity sensor FLNTU manufactured by Wetlabs provided good readings during all CTD casts. The exact configuration of the CTD system can be found in Table 5.1.

Processed preliminary CTD data, 5-dbar binned, was sent in near real time to the Coriolis Data Centre in Brest, France, (via email: codata@ifremer.fr) for integration in the databases to be used for operational oceanography applications and the WMO supported GTS/TESAC system.

Table 5.1. Summary of CTD system SBE #6 configuration used during M189.

Sensors	CTD system SBE#6
Pressure sensor	# 1149
T primary	# 2463
T secondary	# 2120
C primary	# 2443
C secondary	# 3959
O2 primary	# 2588
O2 secondary (profiles 1 to 40)	# 0145
O2 secondary (profiles 41 to 94)	# 1314

The calibration of the conductivity and oxygen sensors was conducted following the recommendations in the GO-SHIP manual (https://www.go-ship.org). For the calibration of the conductivity sensors 214 measurements with a precision salinometer were used (see subsection 5.1.2). For the calibration of the oxygen sensors 440 measurements of the dissolved oxygen content using Winkler titration were used (see subsection 5.1.3). The conductivity calibration using linear correction terms in P, T, C and time resulted in a root mean square (rms) salinity misfit of about 0.0025 PSU for both conductivity sensors after removal of the most deviating 33% of samples (Table 5.2). The oxygen calibration using linear correction terms in T and O, quadratic correction terms in P as well as the product of P and O resulted in a rms oxygen misfit of 1.4 µmol/kg for the primary oxygen sensor (#2588) and 0.7 µmol/kg for the replacement secondary oxygen sensor (#1314). For the oxygen sensor that was initially used as secondary sensor (#0145 O_2) no reliable calibration was possible. For the final data the primary string of sensors was selected because of the continuous use of the same oxygen sensor.

Table 5.2 End of cruise salinity, oxygen and pressure summary of downcast calibration information for the CTD system used during M189.

CTD system SBE#6		
Sensor pair	**Primary**	**Secondary**
RMS misfit after calibration - salinity	0.0024	0.0027
Polynomial coefficients - conductivity	Cond #2443 Offset: -0.00041256 P1: +1.9058e-07 T1: +7.9279e-05 C1: +1.1932e-05 Time: +1.5209e-05	Cond #3959 Offset: +0.037733 P1: +1.2254e-06 T1: +0.0014909 C1: -0.013821
RMS misfit after calibration - oxygen	1.48	0.73
Polynomial coefficients - oxygen	Oxy #2588 Offset: 2.9562 P1: -0.0025493 P2: +4.977e-07 T1: -0.13386 O1: -0.013061 P*O: +7.1916e-06	Oxy #1314 Offset: 9.6069 P1: -0.012176 P2: +1.8237e-06 T1: -0.37997 O1: -0.031464 P*O: +2.8447e-05
Pressure sensor correction (deck-offset)	0.21	

5.1.2 Salinometer Measurements for Conductivity Sensor Calibration

(B. Friedrich, J. Perschon)

During the cruise, a total of 260 water samples for conductivity measurements were taken for the calibration of the CTD and Thermosalinograph (TSG) conductivity sensors (including TSG samples for cruise M188). From conductivity the salt content can be derived. The samples were filled in ‘Flensburger’ bottles, which during their cleaning rested for about 30 minutes in about 40°C warm water to remove remnants of salt of prior measurements. The measurement was done using the GEOMAR OPTIMARE Precision Salinometer (OPS) SN010. Even though the measurements showed a small temporal drift of 0.001 to 0.0025 PSU to higher salinities over each measurement cycle, it was decided to continue the usage of the instrument.

The measurement procedure always remained the same: The empty bottles were prepared before usage as described above. After each CTD profile one sample of one to two depths were filled into the bottles. After a whole crate (20 ‘Flensburger’ bottles) was filled, the crate was put for 3-4 hours into a 40°C water bath and afterwards shortly opened to degas. This step was necessary as the OPS is known to be sensitive to micro bubbles in the water. The crate was then brought to the Gravimeter room, which is a closed room with constant air temperature of 23.5°C. There, the crate remained untouched overnight so that the water could adjust to room temperature as the measurement is quite temperature dependent.

The measurement cycle itself started by rinsing the cell 10 times with old standard sea water to make sure that the conductivity cell is filled completely with salt water. This was followed by a standardization of the instrument for which a new bottle of IAPSO Standard Sea water was used. Before the measurement of the first actual samples and after every 5th bottle, a substandard was measured to determine the drift of the OPS. The substandard was taken from a deeper CTD profile and filled into two 10-liter tanks. Sadly, this led to quite different salt contents as the tanks had not been cleaned beforehand. It was decided to fill the content of one tank into ‘Flensburger’ bottles and use this further on as substandard. In the following measurements large variations in the salt contents of the substandard were measured, so that a new substandard was taken and directly filled into the 'Flensburger' bottles. This led to more stable substandard values.

After each crate a substandard was measured again, followed by a measurement of a new standard sea water bottle. Before standby of the OPS, the instrument was rinsed 10 times with distilled water and the needle stayed rested in the distilled water.

5.1.3 Oxygen Winkler Measurements

(D. Pöhnl, L. Mock)

From the majority of CTD rosette system deployments, water samples for an oxygen concentration analysis were taken from Niskin water bottles. At the beginning of the cruise, duplicate samples of three depths were taken from each CTD profile. Onward from CTD profile 38, sampling strategy was changed to triplicate samples for two depths. All CTD profiles were sampled, apart from profiles 1, 2 and 60. Furthermore, due to erroneous titration results, data from profiles 40 and 50 to 56 were removed from the final concentrations. Overall, 91 CTD profiles were sampled over the whole duration of the cruise. Samples were generally taken from Niskin bottles that were closed during the upward cast. However, during a few shallow profiles that were used for biogeochemical water sampling, the Niskin bottles were closed while the CTD was on its way down. Water sampling was performed by a representative of the CTD group on watch. The samples were then covered and stored for later analyzed using the Winkler method. For each new day of water sample analysis, new titers were prepared amounting to 14 different sodium thiosulphate calibration factors.

5.1.4 Thermosalinograph

(L. Aroucha, F. Awo, G. Krahmann)

Continuous underway measurements of Sea Surface Temperature (SST) and sea surface salinity (SSS) were made by the ship's dual thermosalinograph. The system consists of two devices, with one inlet placed at the portside (TSG1) and another inlet situated at the starboard side (TSG2). The parallel system worked well throughout M189, although slight discrepancies could be observed between both, especially regarding the salinity measurements during the mesoscale eddy survey between 15ºS and 17ºS (Fig. 5.1) and in general when the ship was close to the coast. Gaps in data between 20ºS and 17ºS are explained due to the switching off of the TSG system when leaving the Walvis Bay port in the second sailing while the vessel steamed within Namibian territorial waters. Daily water samples were taken directly from the TSG system and their salinity determined with the Optimare Salinometer. All TSG data and the daily salinity values were transmitted to the colleague of the 'Deutsche Allianz Meeresforschung' for final processing, calibration, quality control and publication.

In general, higher temperatures were found in the northern area off Angola with temperatures above 29ºC. In Namibian waters, the temperatures drop to below 19ºC (Fig. 5.1). The biggest shifts in temperature are associated either with the shelf break, where elevated vertical mixing cools the SST, and the cyclonic eddy. In the latter, mesoscale dynamics generate lower temperatures at the eddy core (around 16ºS). Regarding salinity, freshwater intrusions associated with the Congo River outflow could be observed from northern Angola until 14ºS (Fig. 5.1). This freshwater transport to further south of 12ºS is climatologically unexpected for this period of the year (Awo et al., 2022). As argued for temperature above, vertical mixing could be playing an important role in setting sea surface salinity, since even in waters under the influence of the Congo River discharge, higher salinities were observed close to the coast (from 9ºS to 14ºS).

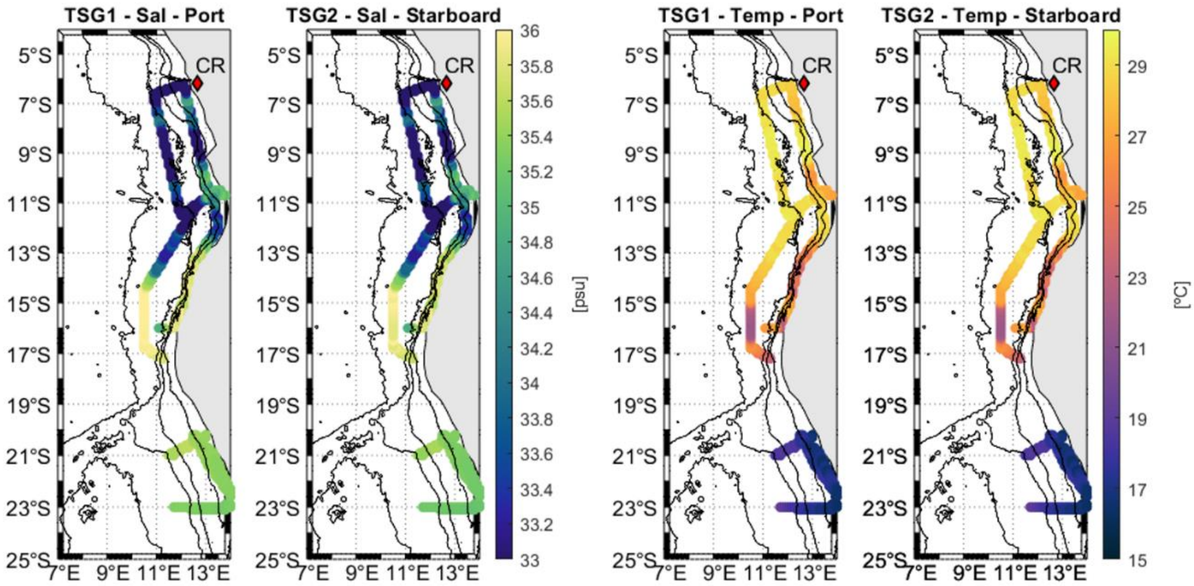

Fig. 5.1 TSG measurements for salinity (left side) and temperature (right side) for both Port (TSG1) and Starboard (TSG2) inlets off Angola and Namibia during M189. From coast to offshore the 200m,1000m, 2000m, and 4000m isobaths are shown.

5.1.5 Moving Vessel Profiler

(L. Aroucha, G. Krahmann)

At portside astern we deployed a Moving Vessel Profiler (MVP) from AML MVP30-350 S/N M12399 with a CTD probe (MVP-X 9068) and a Turner Cyclops-7F Fluorometer (S/N 21101080). The MVP winch was mounted on a base constructed by GEOMAR to launch the instrument.

The dropsonde reached depths of about 150 m and was in use intermittently from April 26 to May 5. During the cruise, the MVP was used to survey 3 hydrographic sections. Among them was a 248 nautical-mile-long meridional section across a mesoscale cyclonic eddy in the Angola-Benguela-Frontal-Zone, which was taken between April 26 and April 27 (Fig. 5.2). A second section was taken between 7°S and 8°S on May 2 over a distance of 153 nautical miles. While sampling, the cable broke, so the section could not be completed as desired. Once the cable was repaired, a third section perpendicular to coastline at 11°S was taken from the evening of May 5 to the early morning of May 6. The data was processed followed standard routines, which also corrected the thermal lag of the temperature sensor.

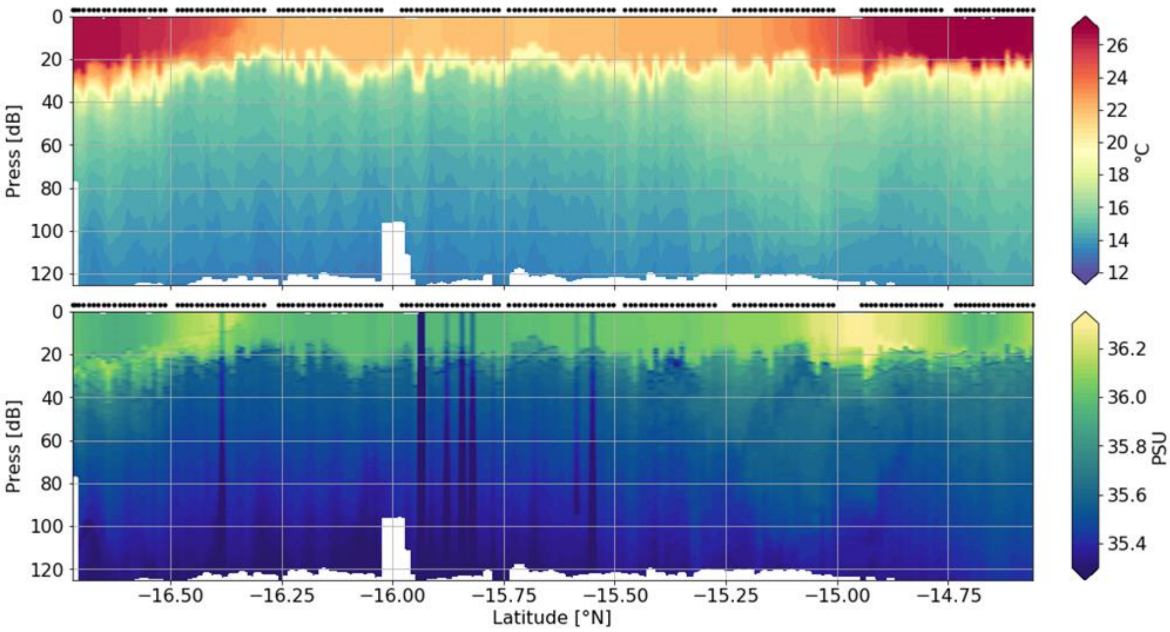

Fig. 5.2 Temperature (top, in °C) and salinity (bottom, practical salinity scale) measured by the MVP as a function of pressure (decibar) and latitude during the transect across a mesoscale cyclonic eddy taken from April 26 to April 27.

5.2 Current Observations

5.2.1 Vessel-Mounted ADCP Measurements

(M. Körner, R. A. Imbol Kounge, M. Dengler)

During the cruise, two vessel-mounted ADCPs (vmADCPs) were used to measure current velocities in the upper ocean. The 75-kHz RDI Ocean Surveyor (OS75) provides measurements with high vertical resolution, while the 38-kHz RDI Ocean Surveyor (OS38) observations can reach deeper at the cost of coarser vertical resolution. The OS75 was installed in the moon pool of the ship while the OS38 was mounted into the ship's hull. Both ADCPs used narrowband mode pings. The OS38 was configured with 80 bins of 16 m length and a blanking distance of 8 m, with a range of 1200 m. The OS75 was configured with 10 bins of 8 m length and a blanking distance of 4 m, reaching the depth of about 800 m.

At the beginning of the cruise, the OS75 was not ready for measurements due to set up issues. Thus, we started the velocity observation using only OS38. The measurements of the OS75 was started on April 19. On April 25, both ADCPs were turned off due to custom clearance at the Walvis Bay harbour. Sampling was continued after reaching the Angolan EEZ on April 26. During the transit from Walvis Bay to the Angolan EEZ, the OS75 was removed from the moon pool, requiring a separate water track. While measuring in deeper waters upon entering the Angolan EEZ, we noticed interference in the backscatter amplitude and velocity data of the OS75 (Fig. 5.3 a). They had also been present before but stayed unnoticed as we were measuring in shallow waters. After a few tests, it was found that the OS38 was interfering with the OS75. Both vmADCPs were built into the ship with an angle of 45° relative to the ship's forward axis. We suspected that this was the reason for the interferences. It was decided to turn off the OS38 upon reaching shallow waters at 11°S section, as in this region the OS75 provides current observations of the whole water column. After turning off the OS38, the interfering signal was gone (Fig. 5.3 b). We decided to measure with the OS75 alone while being in shallow waters to get enough data to determine the misalignment angle and amplitude factor well. On the May 2, we removed the OS75 from the moon pool again and rotated it such that it installed at a 0° angle relative to the ship's forward axis. Afterwards, both vmADCPs were turned on again. There were some minor interferences in the OS75 backscatter but overall, the signal was much clearer and the interferences were not visible in the velocity data (Fig. 5.3 c). This setup was used until the end of the scientific measurements on May 10.

The final post-processing, quality control and publication of the Ocean Surveyor data will be carried out by our colleague of the Deutsche Allianz Meeresforschung (DAM) within the Underway Research Data project. However, mean misalignment angles and amplitude factors with the associated standard deviations used during the cruise are summarized in Table 5.3. As the OS75 was removed twice from the moon pool during the cruise, mean misalignment angles and amplitude factors were calculated for each deployment period respectively.

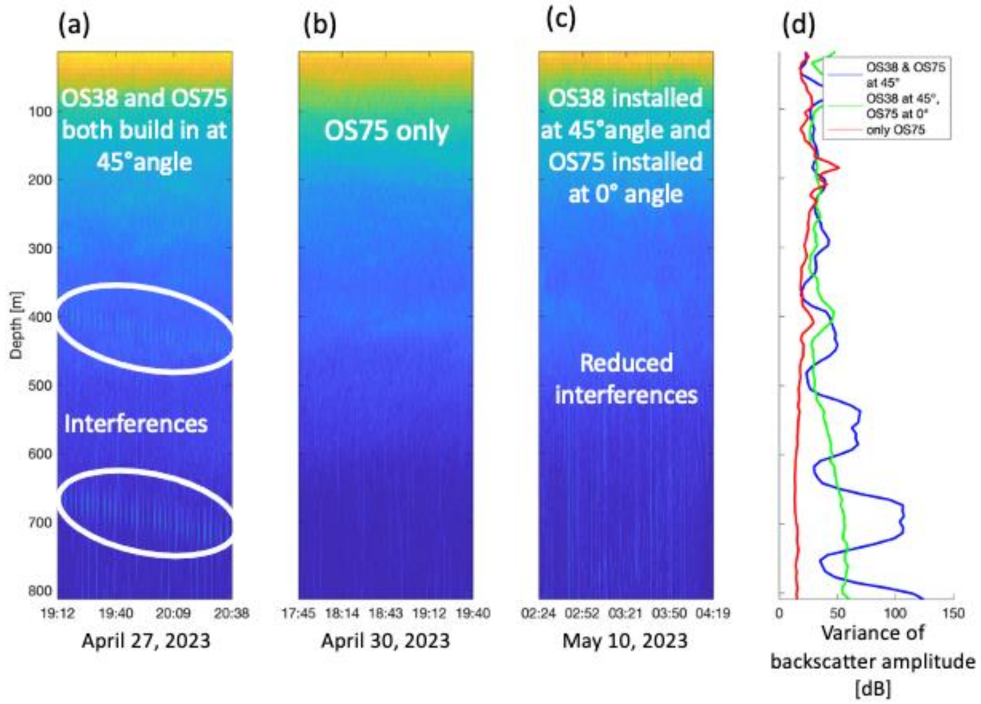

Fig 5.3 Backscatter amplitude of the OS75 during different setups of the instruments.

Table 5.3 Vessel-mounted ADCP calibration.

Period	ADCP	Mode	Misalignment angle ± std	Amplitude factor ± std
19 April 2023 – 25 April 2023	OS75	NB	0.2217° ± 0.6618°	1.0149 ± 0.0144
26 April 2023 – 02 May 2023	OS75	NB	0.1887° ± 0.5813°	1.0069 ± 0.0099
02 May 2023 – 10 May 2023	OS75	NB	-0.2128° ± 0.475°	1.0036 ± 0.0076
16 April 2023 - 7 May 2023	OS38	NB	0.2033° ± 0.7281°	1.0036 ± 0.0177

5.3 Drifting Buoy and Surface Drifter

5.3.1 Drifting Buoy

(J. Söder, N. Reese)

During M189, a drifting buoy equipped with a chain of hydrographic instruments was deployed twice. The aim was to study high-frequency hydrographic phenomena such as near-inertial waves, tidal waves, and non-linear internal waves. With these datasets we bridge the gap between long term observations in the area with moorings (section 5.4) and measurements of very short-lived phenomena like turbulence (section 5.5).

The first deployment was done at the 23.5°S transect, the second one at the 20.5°S transect, both at a water depth of 200 m. Therefore, both deployments where co-located in space and time with shipboard CTD and microstructure measurements. On both drifters we used a GPS-Iridium tracking device to determine position and drift speed and a small secondary buoy for wave observations (Sofar Spotter). This secondary buoy uses acceleration and GPS sensors to provide a secondary location source as well as wave heights and directions. This allows assessing wave properties independent of the comparatively large buoyancy oscillations of the main buoy. Below the main buoy, we mounted a thermistor chain with one device every 5 m. Furthermore, an upward and a downward looking ADCP were used to provide high-resolution current measurements. Salinity, oxygen and pressure were monitored as well. A detailed list of the performance of the instruments and deployment data is provided in 7.3.3. All devices performed flawlessly, apart from the downward facing ADCP that was flooded during the deployment at 23°S and stopped operating after 10 h.

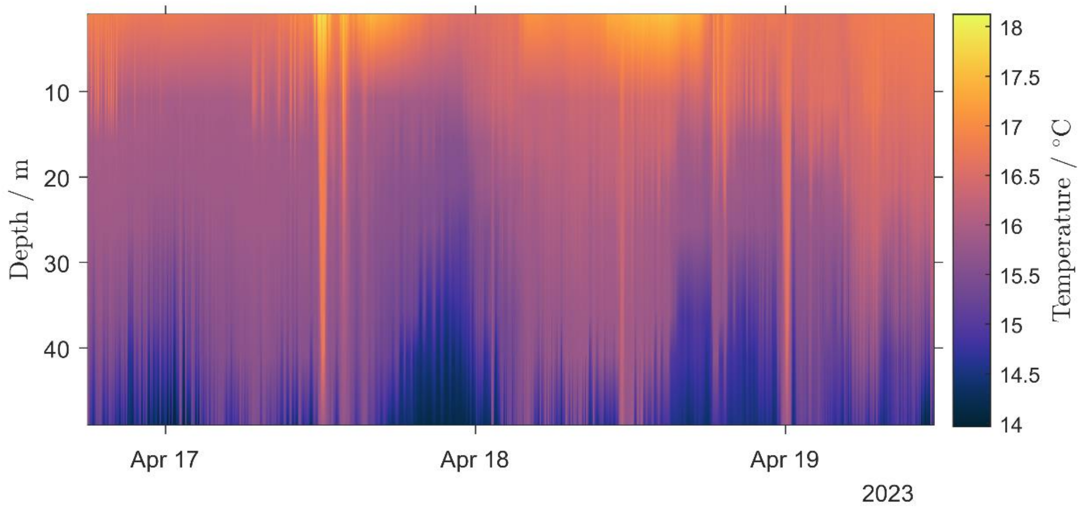

Fig. 5.4 High-resolution temperature observations provided from the first deployment of the IOW drifter.

In Figure 5.4 we provide preliminary results from the thermistor chain. The data show a superposition of several waves: high frequency non-linear internal waves with a period in the order of ten minutes as well as lower frequency internal waves with a in the order of a few hours. These waves lead to strong vertical transport, which can be seen by advection of warm surface water down to depths of more than 40 m. Furthermore, the track of the drifter exhibited anticyclonic rotation that are likely associated with a near-inertial wave. The period of this wave was about 30 h.

5.3.2 HEREON Surface Drifter

(Y. Wölker, M. A. Mrozowska, M. Dengler)

Between April 29 and 30, 12 HEREON surface drifters were deployed on 4 positions along the continental slope and shelf of Angola between 10.9°S, 13.5°E and 11.5°S, 12°E (Fig. 5.5, Table 7.3.1). The drogue of the HEREON drifters is attached just underneath the drifting buoy. Thus, they follow currents in the first meter of the ocean. For two of the 12 drifters (SN307 and SN308, Fig. 5.5, Table 7.3.1) an additional high-frequency sampling GPS was installed. These satellite fixes were recorded internally.

During the first step of the deployment procedure, the batteries of the drifters were connected activating the GPS and mobile satellite phone. Then, the drifters were lowered into the water using a rope at the stern of the ship. Out of the 12 released drifters, three were recovered and one was most likely caught by local artisanal fishermen. Drifter SN308 was recovered on May 5 using the GPS position data, a predicted drifter track and able observes at the bridge. When spotted, the instruments were picked up by two scientists and one crew member on the rubber boat. Two days later, on May 7, the drifters SN271 and SN276 were recovered using the same methods. The data from the other internally recoding drifter SN307 was received a few months after cruise termination as the drifter was washed on shore close to Lagos, Nigeria. A Nigerian colleague was able to secure the drifter and returned the data during a visit to GEOMAR in October 2023.

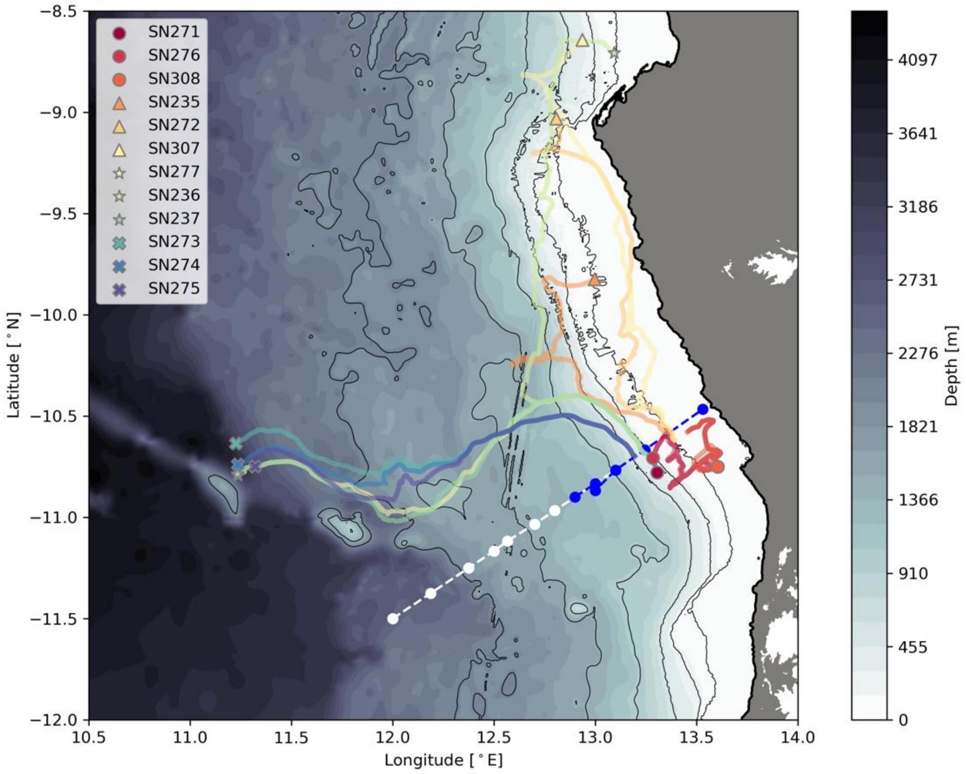

Fig. 5.5 Ship track (white and blue) and drifting paths of the 12 deployed HEREON drifters. The markers show the most recent drifter positions as of May 9, 2023, 12:55 UTC. Depth contours of topography are 50m, 100m, 200m, 500m, 1000m and 2000m.

The drifter tracks until May 9 are presented in Fig. 5.5. The water depths of the drifter release site were 450m, 200m, 100m and 50m. Drifters release at a depth of 100m or larger generally moved northward and partly offshore. This was likely due to the presence of an anticyclonic eddy at the release sites that is also visible in satellite altimetry (not shown). Drifter SN236 picked up speed early on, which was uncharacteristic of expected surface currents, and stopped transmitting data on the May 4 at 11:28 UTC. We therefore deduce that it was most likely caught and brought to shore by a fishing vessel.

5.4 Mooring Operations

(J. Söder, M. Körner, R. A. Imbol Kounge, N. Reese, M. Dengler)

During the cruise, three long-term moorings that are an integral component the ocean observing system off Southwest Africa were serviced. Additionally, a short-term mooring array sampling ocean velocity and hydrography at high temporal resolution was deployed and recovered. The mooring deployments and recoveries are summarized in Table 5.4.

Table 5.4 Summary of mooring operations during M189. Upper table shows deployments while lower table shows recoveries.

M189 mooring recoveries					
Mooring	**ID**	**Latitude**	**Longitude**	**Deployment Date**	**Recovery Date**
LTMB	LTMB_28	22° 59.68' S	014°03.39'E	17-Jan-2022	17-Apr-2022
NBUS WBST	EAST-11	23°01.24’S	014°01.99’E	25-Jan-2022	17-Apr-2022
13°E 11°S	KPO_1246	10°49.87’S	012°59.93’E	24-Apr-2022	04-May-2023
SM 200m	KPO_1273	10°41.71’S	013°17.18’E	29-Apr-2023	07-May-2023
SLM2 100m	KPO_1275	10°37.16’S	013°23.46’E	29-Apr-2023	07-May-2023
SLM1 50m	KPO_1274	10°33.08’S	013°30.63’E	29-Apr-2023	07-May-2023

M189 mooring deployments					
Mooring	**ID**	**Latitude**	**Longitude**	**Deployment Date**	**Recovery Date**
LTMB	LTMB_29	23°00,047`S	14°02,985`E	19-Apr-2023	
NBUS WBST	EAST-12	23°01.362’S	014°02.181'E	19-Apr-2023	
SM 200m	KPO_1273	10°41.71’S	013°17.18’E	29-Apr-2023	07-May-2023
SLM2 100m	KPO_1275	10°37.16’S	013°23.46’E	29-Apr-2023	07-May-2023
SLM1 50m	KPO_1274	10°33.08’S	013°30.63’E	29-Apr-2023	07-May-2023
13°E 11°S	KPO_1272	10°50.07’S	013°00.01’E	06-May-2023	

5.4.1 Long-Term mud Belt Mooring off Namibia

IOW operates a long-term mooring on the Namibian shelf at a water depth of about 130 m. We aim to evaluate the variability of eastern boundary current transport as well as the variability in the advection of anomalous water masses along the eastern boundary with these data. Furthermore, wave propagation along the southwest African coastal wave guide shall be studied.

Due to its long-time span, this data set provides a unique opportunity in this region to evaluate long term trends related to climate change. A preliminary plot of the temperature record is given in Figure 5.6. To retrieve such a long data records, regular servicing of the mooring is required. This has been carried out during M189, where we successfully recovered the instruments of LTMB 28 on 17 April 2023. The importance of this regular maintenance is hidden in the temperature time series: Due to the Covid-19 pandemic we had to skip one maintenance operation. This caused the mooring rope to break with subsequent loss of devices and data between 2019 and 2021.

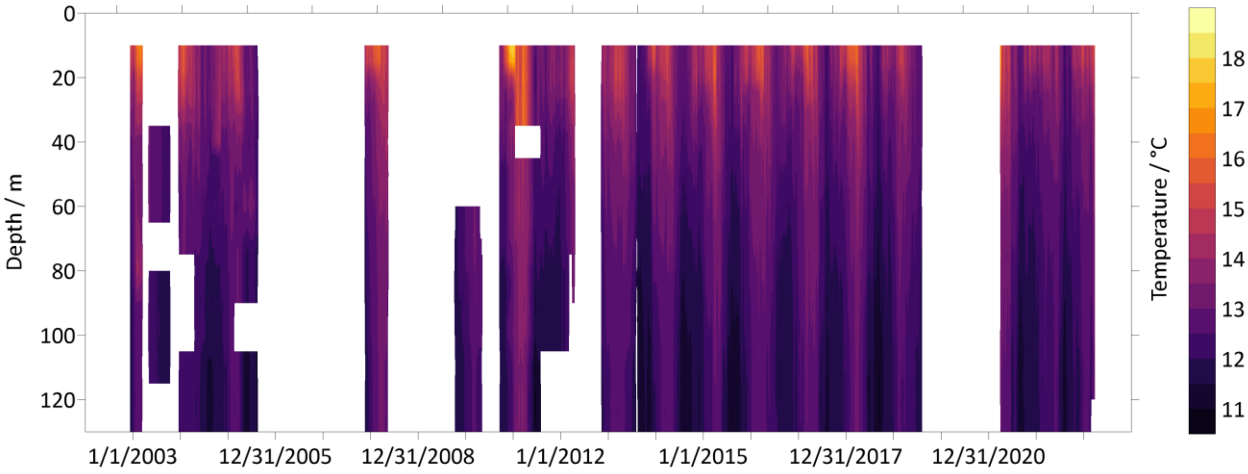

Fig. 5.6 Temperature record from the LTMB mooring in Namibian waters

The performance of the individual devices during the last deployment is detailed in Table 7.4.1. The mooring was equipped with nine RBR temperature recorders, three miniDOT oxygen loggers, five Seabird thermosalinometers, two Wetlabs turbidity meters and one upward facing 300 kHz ADCP. During a first evaluation, the instrument data show that the mooring had progressively sunken into the mud on the seabed. Therefore, pressure data are available from the instruments below the ADCP, only. This caused all instruments to be located 10 m below their intended mounting depth. We established that this was caused by the use of a new ground weight with a small footprint. Therefore, we are confident that it can be avoided in the future. The instruments operated by IOW in the LTMB mooring were calibrated in the IOW calibration lab prior to their deployment. Velocity data from the ADCPs were corrected for magnetic declination according to the WMM model from NOAA.

Subsequently, the mooring was successfully redeployed on 19 April 2023. A summary of the attached instruments is shown in Table 7.4.1. The number of instruments was reduced when compared with previous deployments as instruments are needed to fulfilled other obligations. The mooring was deployed with a T-shaped ground weight made of concrete in order to prevent it from sinking into the mud. Furthermore, the distance of the ADCP to the ground was reduced so that high-current events like internal tidal bores can be observed as close to the bottom as possible.

5.4.2 Sediment Trap Mooring

Sediment trap studies have been successfully conducted in the northern Benguela Upwelling System (NBUS) in the past as part of the GENUS (2009-2015) and TRAFFIC (2018-2022) research projects (Vorrath et al., 2018, Emeis et al., 2018). The aim of the sediment trap deployments is to investigate the spatial and temporal variation in the deposition of particles from the sea surface to the seabed (Tab. 5.3). Particle flux studies are an important link between sea surface processes (e.g. primary productivity) and seabed sedimentation and accumulation of particles, and are therefore an invaluable tool for understanding the sedimentation record. Detailed compositional and specific organic compound analyses will provide insight into the sources, early diagenetic transformation and transport processes of particulate organic material in the water column. Although the project funding ended in 2022, Hamburg University (Germany), together with NatMIRC in Swakopmund (Namibia), has intended to continue these studies to uncover long-term changes and investigate the energy transfer from the shelf to the open ocean.

During the cruise the long-term sediment trap mooring (WBST East-11) at the Walvis Bay transect (23°S) was successfully recovered. Both the sediment trap (HYDROBIOS MST-12) and the MINI-Dot oxygen sensor took samples throughout the mooring period and provided 12 sediment trap samples and a one-year oxygen record, respectively. A summary of this operation is given in Table 7.4.1. The sediment trap system (WBST-12) was redeployed with the same mooring settings on 19 April 2023 at 130 m water depth. The sediment trap was installed 75 m below sea surface and a sampling interval of 30 days for each rotation interval, starting on 20 April 2023 and ending on 14 April 2024 was chosen.

A first preliminary evaluation of the quantitative particle flux based on the filling of the sediment trap cups of WBST East-11 shows different flux amounts during the recording period (Figure 5.7). A seasonal trend is not discernible here, although this can still change both qualitatively and quantitatively during the evaluation in the home laboratory.

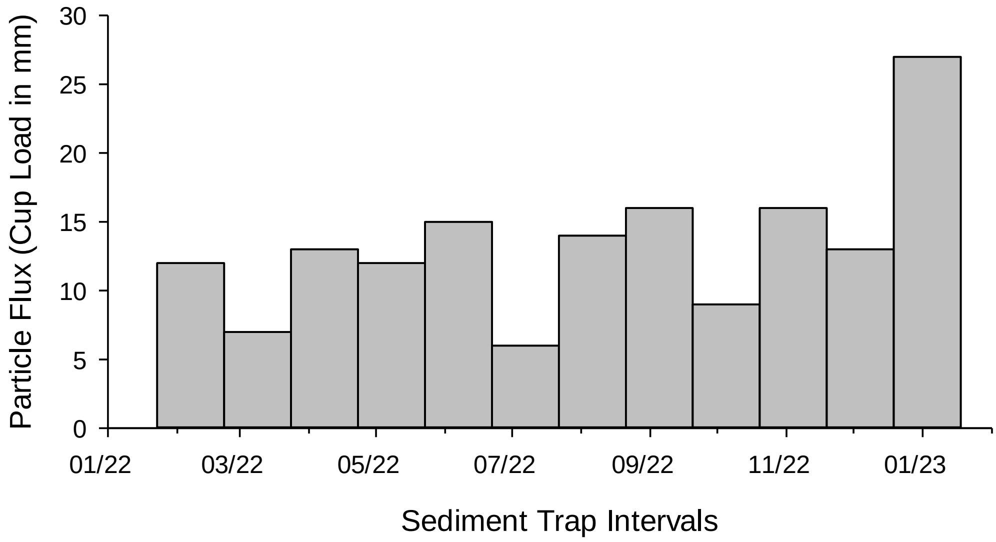

Fig. 5.7 Preliminary particle load of WBST East-11 derived from cup measurements in arbitrary units.

5.4.3 Long-Term Mooring off Angola at 12°S

Since June 2013, a current meter mooring deployed in 1200m water depth at 10°50’S, 13°E is monitoring the eastern boundary circulation of the tropical Angolan upwelling region. The current meter records have been fundamental to recent advances in the understanding of the eastern boundary circulation and its variability off Angola (e.g. Körner et al., 2024) and the dynamics of the Benguela Niños and Niñas (e.g. Imbol Koungue et al., 2021, Imbol Koungue et al., 2024)

The Angolan mooring (KPO_1246) was successfully recovered in the afternoon on May 4. The quality and quantity of data collected by the moored instruments was also very satisfying. The upward-looking ADCP (75 kHz RDI-Long Ranger) attached to the mooring at about 500m depth provided a complete and clean record (Fig. 5.8). All 5 temperature-conductivity recorders (Micro-CATs) moored at about 305 m, 505 m, 705 m, 952 m and 1202 m produced good and clean records. They were sampling at an interval of 15 minutes. The two oxygen loggers attached to the mooring at about 305 m and 505 m also performed well and provided clean records. Finally, the three single point current measurements (Aquadopps, nominal depths of 654 m, 850 m and 1047 m) performed well and provided full and clean records using a sampling interval of 30 minutes.

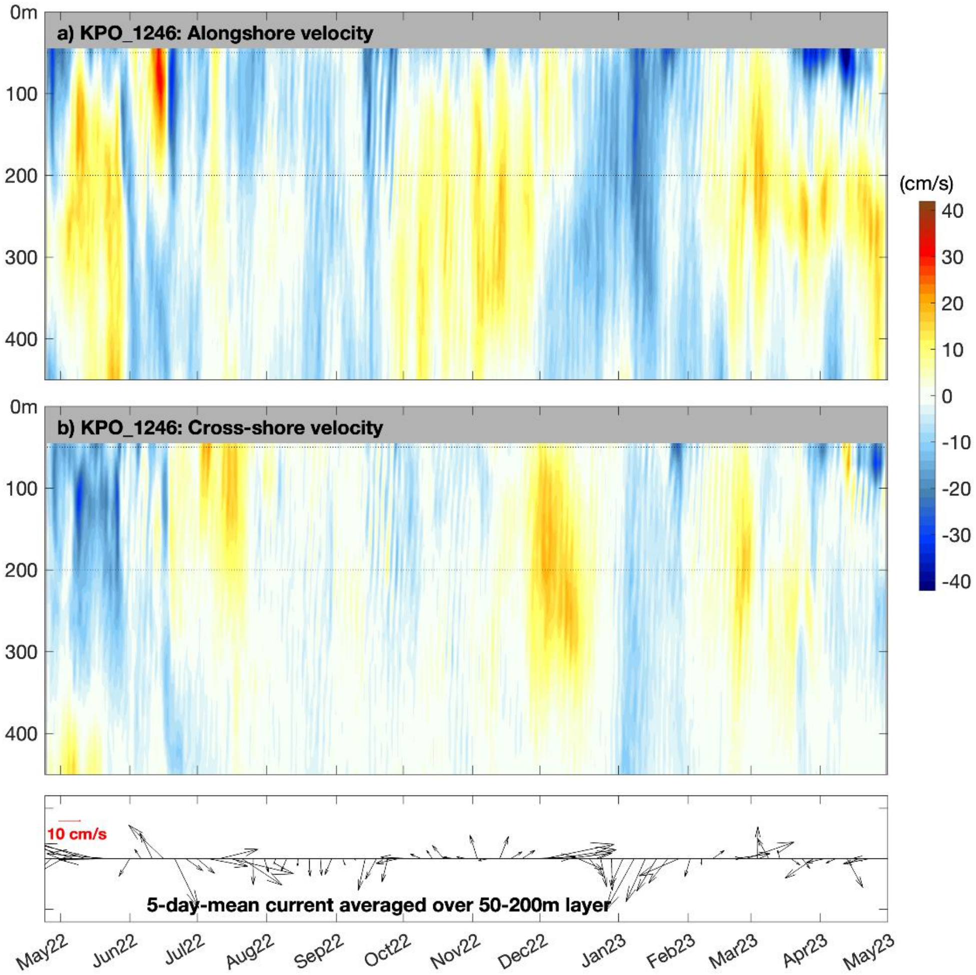

Fig. 5.8 Alongshore (upper panel) and across-shore (middle panel) velocity measured by the upward-looking ADCP mounted at 500m depth to the mooring off Angola at 12°S (KPO_1246). The lower panel shows upper ocean velocity vectors determined by 5-day averaging velocity between 50m and 200m depth.

The alongshore and cross-shore time series from this deployment (Fig. 5.8) exhibit similar enhanced baroclinic intraseasonal variability as found during previous years that is largely due to coastal trapped waves propagating poleward. Enhanced poleward velocity in June through September and December through January are due to upwelling coastal trapped waves that are forced by changes of the winds in the western and central equatorial Atlantic (Körner et al., 2024b).

5.4.4 Short-Term Mooring Array

In the Angolan waters, a short-term current meter mooring array was deployed along 12°S section as part of the upwelling process study. An array of similar configuration was deployed during the main period (June-July) during R/V METEOR cruise M148. The major aim of the array deployment was to provide background information of the velocity on the continental shelf during the glider-sampling period and to collect a data set that is comparable to the previously deployed array so it can be contrasted to the velocity records from the upwelling period.

Two landers (KPO_1274 and KPO_1275) and one short-term mooring (KPO_1273) were deployed in the afternoon of April 29 and recovered on May 7. The lander KPO_1274 was installed at 50 m depth (Fig. 5.9) carrying an upward-looking ADCP, CTD and O_2 loggers. The other lander KPO_1275 carried the same instruments and was installed at 100 m depth. The short-term mooring KPO_1273 was installed at the 200 m isobath (Fig. 5.9). It carries a uplooking Nortek Signature 55 kHz ADCP. All moored instruments worked well and provided full and clean data records.

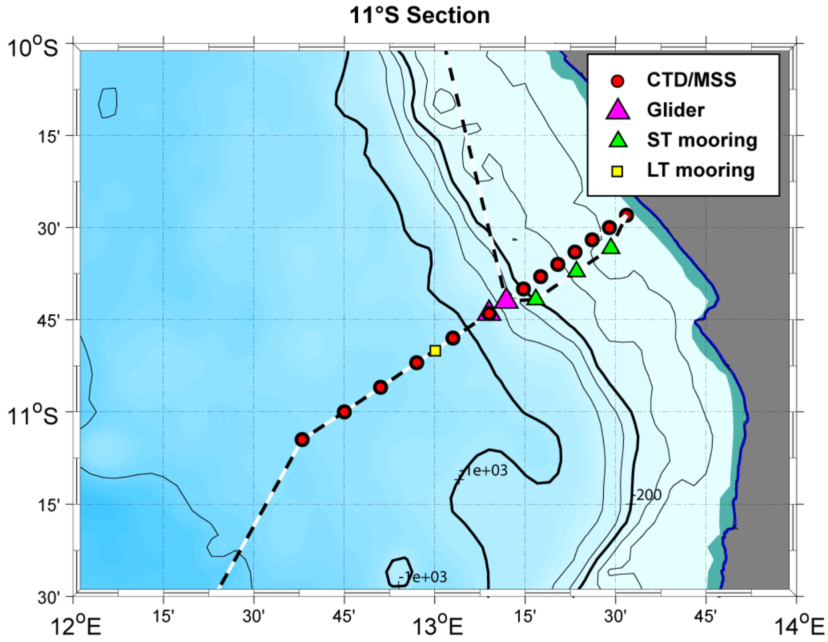

Fig. 5.9 Bathymetric map showing the position of short-term mooring array (green triangles), glider deployment (magenta triangles) and the long-term mooring position (yellow square).

5.5 Shipboard Microstructure Measurements

(M. Körner, J. Söder, M. Dengler)

A MSS90-D II microstructure (MSS) profiler (SN 073) manufactured by Sea & Sun Technology was used to infer dissipation rates of turbulent kinetic energy. This turbulent quantity can be used to estimate diapycnal fluxes of solutes, heat and momentum and advances our understanding of the dissipation of tidal energy at the continental margin. The loosely tethered profiler was equipped with 3 airfoil shear sensors, a fast thermistor, and an accelerometer, as well as additional sensors such as pressure, conductivity, temperature, oxygen, and turbidity sensors. The sink velocity of the profilers was adjusted to about 0.55 m/s.

In its original set up, the MSS profiler is equipped with a protective cage for the sensors. During this cruise, a special protective cage was used the minimizes the production of Kármán vortex streets behind the cage and thereby reduces the noise level of the MSS by about a factor of 6. This was achieved by replacing the ring of the standard cage with a 3-D printed, airfoil-shaped structure of 5 cm length, with additional fairings at the trailing edge of the structure. The airfoil structure printed was profile NACA 0015.

In total, 509 profiles to a maximum depth of 388 m were recorded on 92 MSS stations (Table 7.5). Due to a file naming mistake, there is no profile with the number 0139. Thus, the names of the raw files end at 510, although there were only 509 profiles taken. During the cruise, we conducted MSS observation in different survey areas that are summarized in Table 5.5.

Table 5.5 MSS profiles taken in the different survey areas.

Survey area	Number of Profiles	Profile IDs
23°S section	56	0001-0056
20.5°S section	48	0057-0104
NLIW experiment	58	0105-0163
11°S section	290	0164-0236, 0282-0498
6°S section	45	0237-0281
Cage experiment	12	0499-0510

MSS profiles were taken at 4 different cross-shelf sections (23°S, 20.5°S, 11°S, and 6°S), where we normally sampled 3 MSS profiles at each MSS station following a CTD station. At 11°S we additionally conducted 2 high-resolution MSS sections where we steamed onshore with 1.5 kn while continuously profiling. During those sections, MSS profiling was only interrupted for CTD stations. Additionally, MSS profiles were taken from the rubber boat in the shallow part of the 11°S section. To do so, the MSS profiler was attached to a cable of 100 m length, which we lowered and raised by hand. Power was supplied by a car battery protected in a Zarges Box. Unfortunately, due to limited power available and due to problems of the rubber boat engine, only 8 profiles could be collected. These 8 profiles were named separately from the MSS profiles taken on the vessel. While the rubber boat returned to R/V METEOR, it was hit by a surface wave which resulted in a broken shear sensor (s/n #133). Thus, shear sensor 3 was changed after profile 411 (Table 5.6).

Table 5.6 Configuration of shear sensors mounted to MSS profiler and their sensitivity.

Profile	Shear sensor 1	Shear sensor 2	Shear sensor 3
0001 - 0411	s/n 097 (4.1 x 10^{-4} Vms^2/kg)	s/n 135 (3.92 x 10^{-4} Vms^2/kg)	s/n 133 (4.47 x 10^{-4} Vms^2/kg)
0412 - 0510	s/n 097 (4.1 x 10^{-4} Vms^2/kg)	s/n 135 (3.92 x 10^{-4} Vms^2/kg)	s/n 030 (2.92 x 10^{-4} Vms^2/kg)

During the last stations of the cruise while sampling in the mesoscale eddy at 15°S, the impact of the protective cage on the noise of the shear sensors was investigated. Three different protective cage setups were used (Table 5.7). This was done in order to evaluate the noise level of the instrument and possible influences of the different cages on the dissipation rate measurement. As a reference, we included three profiles without a protective cage.

Table 5.7 Overview of the cage experiment.

Profile IDs	Cage ID	Cage description
499-502	# 1	Steel cage as provided by Sea and Sun Techn.
503-505	# 2	3D printed cage, NACA 0015 shape, printed fairings
506-507	# 3	3D printed cage, NACA 0015 shape, no fairings
508-510		No protective cage

Within the Scientific Committee on Oceanic Research (SCOR) Working Group 160, new standards for determining dissipation rates of turbulent kinetic energy from microstructure shear data during post-processing and data archiving were recently established (Lueck et al., 2024, Fer et al., 2024). At GEOMAR, we will follow the best practices recommendations for data processing and archiving and have tested our post-processing routine to be in line with the recommendations.

Turbulent diapycnal fluxes have recently received pilot status as essential ocean variable (see https://goosocean.org/what-we-do/framework/essential-ocean-variables/). One of the most accurate methods to determine diapycnal fluxes is by measuring microstructure shear using vertical profilers or gliders (Le Boyer etal., 2023) in conjunction with vertical gradients of temperature, salinity and the concentrations of other solutes.

5.6 Glider Measurements

(G. Krahmann, M. Dengler)

An integral component of the observational program was the deployment of gliders to sample the variability of hydrography, oxygen, turbulence, nutrients and various other parameters at high spatial resolution at the 11°S section for a period of 7 days. Three Teledyne Webb Research Slocum gliders (ifm09, ifm13 and ifm14) were deployed during M189 and retrieved later during the same cruise (Fig. 4.3). The gliders were equipped with temperature, conductivity, pressure, oxygen, chlorophyll and turbidity sensors. In addition, a microstructure probe (MicroRider, manufactured by Rockland Scientific) was mounted to the glider ifm09 and an optical nitrate sensor (SUNA, manufactured by Satlantic) was mounted to glider ifm13 (Tab. 5.8). Glider ifm14 carried a prototype Underwater Vision Profiler (UVP) for gliders. The microstructure probe carried two microstructure shear and two microstructure temperature sensors as well as a fast-responding accelerometer and a tilt sensor.

Glider ifm13 was deployed at 11°S on April 29 and sampled the 11°S section twice before its mission ended prematurely on May 5, when it got entangled in the net of a local fishing boat. The fishermen collected the glider and brought it to Port Amboim, Angola. Since the glider was still regularly transmitting position data we were able to locate and contact the fishermen on the next morning and retrieve the apparently undamaged glider. During the 7-day-long deployment the glider managed to dive 225 cycles down to a maximum of 350 m depth and travel a horizontal distance of 180 km.

Glider ifm14 was deployed at 11°S on April 29 and sampled the 11°S section once before its mission ended prematurely on May 5, when its flight pattern showed a sudden change. Luckily R/V METEOR was in the vicinity and the glider was recovered on May, 4. The change in flight pattern was caused by a part of the UVP that had broken off and was dangling off the glider. Nevertheless, all parts were recovered and the UVP had collected data during the whole deployment. During the 6 days, the glider performed 115 dive cycles down to a maximum depth of 350 m and travelled a total of 119 km. The travelled distance and flight performance was significantly worse than that of ifm13. We suspect that the UVP causes a significant amount of drag suggesting that the shape of the UVP might require improvement.

Glider ifm09 was also deployed at 11°S on April 29 but sampled a 6 km long section along the 200 m isobath. Until its recovery on May 5, the glider performed 235 dive cycles and travelled a horizontal distance of 158 km. During this time the glider collected microstructure data without any problems.

Table 5.8 Summary of glider missions.

	Ifm09	**Ifm13**	**Ifm14**
Mission	Depl15	Depl12	Depl08
Survey area	11°S 200 m isobath	11°S section	11°S section
Deployment date	Apr. 29th, 12:00	Apr. 29th, 08:00	Apr. 29th, 9:30
Mission end/Recovery	May 6th, 12:00	May 5th, 16:00	May 4th, 16:00
Sensors	p, T, S, O_2, chl-a, turbidity	p, T, S, O_2, chl-a, turbidity	p, T, S, O_2, chl-a, turbidity
Mounted probes	Microstructure	Nitrate (SUNA)	UVP
Number of profiles	470	450	230
Max. depth (db)	210	350	350

5.7 X-Band Radar

(J. Horstmann)

During the cruise, a coherent-on-receive X-band marine radar developed at the Helmholtz-Zentrum Hereon was installed on the R/V METEOR above the bridge. The radar was operated continuously during the cruise without any failure. It was switched off before entering Walvis Bay port to clear customs and immigration at 06:00 UTC on April 24 and was started again after leaving the territorial waters of Namibia at 11:00 UTC on April 26.

The Hereon marine radar was operated in its rotational mode acquiring radar backscatter intensity images within a range of 3.2 km around the vessel every 2 s at a resolution of 7.5 m in range and 0.9° in azimuth. Therefore, the radar image sequences are analyzed with respect to surface wave properties such as wavelength and phase velocity, where the surface current vector results from the difference of the observed phase velocity to that given by the linear dispersion relation of surface gravity waves. The radar images collected during the cruise will be utilized to observe ocean surface features, such as signatures of internal waves, current shear, surface slicks and fronts. Furthermore, these images will be utilized to retrieve surface current fields with a resolution of approximately 500 m. All of the post processing of this extensive radar dataset will be undertaken by the Radar Hydrography Department of Helmholtz-Zentrum Hereon with particular focus on the observation of internal waves along the Angolan coast close to the shelf.

5.8 Biochemical Measurements

(D. L. Arévalo-Martínez, P. Eisnecker, M. Jacobsen, L. Mock)

Production and emissions of climate-relevant trace gases from the marine environment is crucial for the Earth's atmosphere. Hence the investigation of their distribution and sea-air fluxes is pivotal for better understanding potential responses of the ocean and the overlying atmosphere to environmental changes such as warming and deoxygenation. Low-oxygen waters connected to coastal upwelling systems and the associated oxygen minimum zones (OMZ) are well-known sources of trace gases such as N_2O, CO_2, CO and CH_4. During the cruise we conducted a comprehensive working program involving biogeochemistry and molecular ecology methods in order to investigate the distribution, formation pathways and air-sea fluxes of trace gases, with particular focus on the coupling between nitrogen and sulfur cycles within the OMZ.

5.8.1 Nutrient and H_2S Measurements

Seawater samples for the determination of inorganic nutrients nitrate (NO_3^-) and nitrite (NO_2^-) were collected at selected stations/depths (Fig. 5.10) and will be used to calibrate the SUNA sensor mounted on the CTD-Rosette. Sampling was carried out by drawing 30 mL of seawater directly from the Niskin bottles by means of a 60 mL plastic syringe (after rinsing). Each sample was taken to the lab and filtered through a 0.4 µm syringe filter. Subsequently, a 1 mL sub-sample from each depth was transferred to a 2 mL Eppendorf tube which was then sealed and frozen at -20°C. Samples will be analyzed at the Ecological Microbiology Department of Radboud University in Nijmegen (The Netherlands).

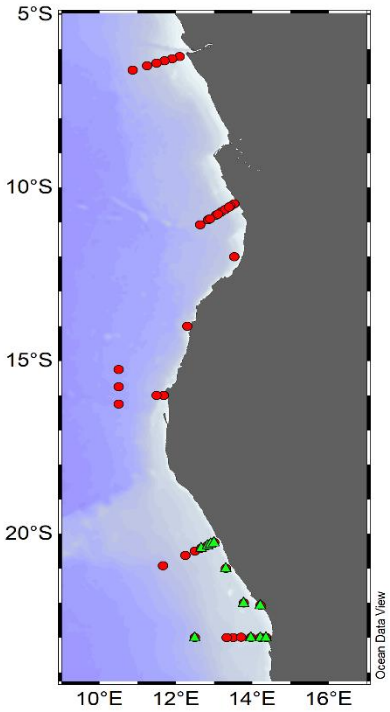

Fig. 5.10 Sampling locations for nitrate NO_3^-, NO_2^- (red dots) and H_2S (green triangles).

In selected stations, where oxygen concentrations were below or close to anoxic levels (0 – 5 µM), samples for the determination of hydrogen sulfide (H_2S) were collected. To this end, a 0.5 mL sub-sample of the same water collected for nutrient measurements was transferred to a 4 mL glass vial, which was prefilled with a 2% solution of Zinc Acetate. Through this procedure, the H_2S present in the samples was chemically bounded, such that measurements can be carried out at the Ecological Microbiology Department of Radboud University in Nijmegen (The Netherlands).

5.8.2 Trace Gas Measurements

Underway Measurements

Continuous measurements of dissolved N_2O, CO_2 , CO and CH_4 in seawater were carried out by means of an autonomous equilibrator headspace setup coupled to an off-axis integrated cavity output spectroscopy analyzer (LGR; N_2O and CO) and a cavity ringdown spectroscopy analyzer (Picarro; CO_2 and CH_4). The combined setup is shown in Fig. 5.11. Water was drawn into the system at ~ 6 L min^{-1} by a LOWARA submersible pump installed in the ship's moonpool (~ 6 m depth). Ambient air measurements were carried out every six hours by drawing air into the system from a suction point located at the ship's mast at about 34 m high. Control measurements were performed every 24 h by means of three standard gas mixtures (Deuste Steininger GmbH) bracketing the expected concentrations in this area. These gas mixtures were calibrated against primary NOAA standards at the Chemical Oceanography Department of GEOMAR Helmholtz Centre for Ocean Research Kiel.

Fig. 5.11 Setup for underway measurements of trace gases during M189. (A) Equilibration system and gas analyzers, (B), reference gases, (C) submersible pump installed at the "moonpool" and (D) inlet for ambient air measurements.

Discrete Sampling

Discrete surface samples for N_2O measurements were collected in 4 – 6 h intervals (Namibian waters) or daily (Angolan waters) by sampling from the ship's inlet to the thermosalinograph. To this end, bubble-free triplicate samples were collected and immediately sealed by means of butyl stoppers and aluminum crimps. Subsequently 50 µL of a saturated mercuric chloride ($HgCl_2$) solution were added. The samples will be analyzed by means of a gas chromatographic setup at the Ecological Microbiology Department of Radboud University in Nijmegen (The Netherlands).

Profile sampling for N_2O and CH_4 measurements was carried out in conjunction with nutrient concentrations and microstructure measurements. Samples were drawn directly from 10 L Niskin bottles mounted on a standard CTD/Rosette. Glass vials of 20 were used and the samples were treated as explained above and will be analyzed at Radboud University in Nijmegen (The Netherlands). The sampling scheme consisted in full coverage of the main features across the oxic-hypoxic-anoxic transition. Nevertheless, the sampling for CH_4 measurements was focused on the upper 200 m of the water column. Table 7.6 gives an overview of the sampling locations and depths during the cruise.

Preliminary Results

Most of the biogeochemical and microbiological measurements will be carried out on land-based laboratories. However, the underway measurement system already provides an overview of the surface distribution of the climate-relevant trace gases measured during the cruise. Generally speaking, larger disequilibrium with respect to atmospheric equilibrium (indicating outgassing from the ocean) could be observed within 50 km of the coast, particularly in the areas between 9 and 11°S (Fig. 5.12). Hence, the tropical Angolan system seems to act a source of trace gases also during the low upwelling season.

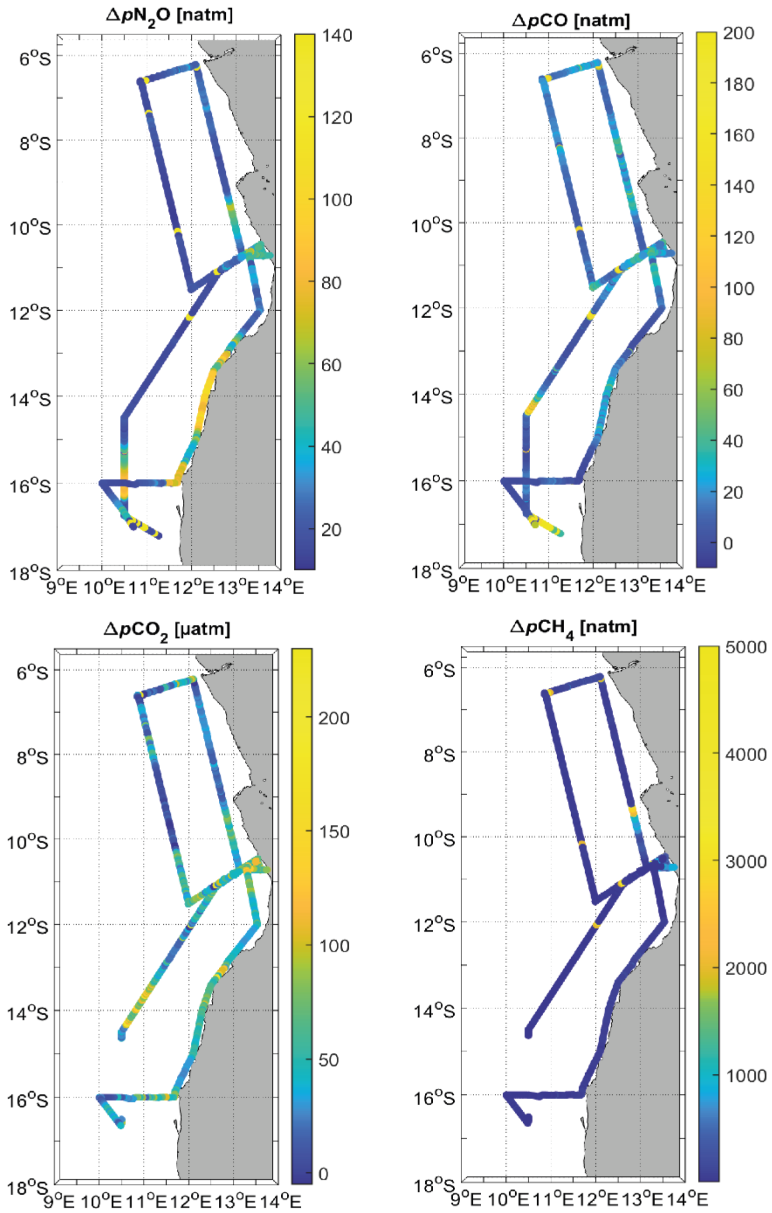

Fig. 5.12 Overview of underway trace gas measurements during M189. Results are expressed in terms of the disequilibrium with respect to atmospheric partial pressures (Δ_{gas}= partial pressure gas $_{seawater}$ – partial pressure gas $_{air}$).

The results of the surveys conducted during the M189 cruise will be combined with similar work carried out during past cruises in the region (M98 in 2013, M120 in 2015, M158 in 2019, M181 in 2022) in order to solve the seasonal variability of trace gases (in particular nitrous oxide) in the region.

5.8.3 Microbial Ecology

To sample water for DNA, Particulate Organic Matter (POM), and Primary Production (PP), bluecap bottles were first rinsed with 2 – 400 mL of water from the sampled depth, after which they were filled with the desired amount of water. DNA samples were taken by vacuum filtering 1 L of water from selected depths over Millipore membrane filters (0.22 µm). The depths usually were composed of the surface (5m), the chlorophyll maximum, 2 arbitrarily chosen depths, and the depth with the lowest oxygen concentration. The filters were then folded with tweezers, placed into Eppendorf tubes®, and immediately frozen at -80 °C. Samples will be kept in cryogenic conditions until analysis, which will be carried out by the group of Prof. Carolin Löscher at the department of biology of University of Southern Denmark, Odense.

Samples for POM were taken by filtering 1 L of water from selected depths over pre-combusted GFF filters. The depths correspond to the DNA sample's Surface, chlorophyll maximum, and the depth with the lowest oxygen concentration. After filtration, the filters were folded with tweezers, placed into Eppendorf tubes®, and dried at 42°C overnight with the lid open. They were then stored at room temperature and in the dark. At most locations, samples were taken in duplicates, but at some later stations, triplicates were taken. The reason triplicates were not always taken was due to material limitations.

For PP, water samples from selected depths were incubated, after which 1 L was filtered over pre-combusted GFF filters. Selected depths and sample treatment were the same as above. For the incubations, 1 mL of 0.235M Sodium Bicarbonate-^{13}C in milliQ® water was added to 2 L of water contained by closed 2l bluecap bottles. The bottles were then kept in an open lid incubator, supplied with a flow-through of surface water, for 24h. A temperature logger was kept in the incubator. The bottles were shaken before filtration to disturb eventual sedimentation and ensure homogenization.

Samples were also taken for analysis of Dissolved Inorganic Carbon (DIC), and Total Alkalinity (TA), alongside pH. For this, triplicates of 12 mL exetainers® were filled with water from all depths in which DNA sampling was conducted. The exetainers were filled by using a syringe to push the water through an Avantor VWR® 0.22 µm membrane filter. To make sure no excess carbon potentially clinging to the filters affects DIC measurements, at least 5 mL of seawater were filtered and discarded with each new filter. Each filter was used to filter water for all 3 exetainers of a triplicate due to material limitations. The syringe was rinsed and reused between samples. The samples were kept refrigerated during the cruise but were shipped back by container.

Analysis of DNA, POM, PP, as well as DIC, TA, and pH samples will be performed by the group of Prof. Carolin Löscher at the department of biology of University of Southern Denmark, Odense.

5.8.4 Underwater Vision Profiler

An Underwater Vision Profiler 5 HD (UVP5 HD; SN 210) was mounted to the CTD rosette during the entire cruise. The instrument consists of a down-facing HD camera in a 6000-dbar pressure-proof case and two red LED lights which illuminate a volume in the water of 1.24 L. During the downcast of the CTD, the UVP5 takes between 6 and 11 pictures of the illuminated field per second. For each picture, the number and size of particles are counted by the internal computer and stored for later data analysis. Furthermore, images of particles with a size larger than 500 µm are saved as a separate "vignettes" - small cut-outs of the original picture – which allow for later, computer-assisted identification of these particles and their grouping into different particle, phyto- and zooplankton classes. Fine-scale vertical distribution of particles and major planktonic groups can be related to environmental data measured by the CTD sensors.

In total 94 UVP5 profiles could be obtained. CTD station 3 was repeated, which is why there exist two corresponding UVP5 profiles. There is no useful profile for CTD station 50 as it was too shallow. Due to time issues, the last CTD 94 was only done to 1000 m depth. Apart from these three occasions, each CTD station has one corresponding full-depth profile as raw data. However, occasionally, the CTD was stopped at some depths for calibration of other devices, which limits the useful data from the UVP. For the on-board processing only one section of each profile with an even rate of descent was considered. Further, computer-assisted analysis of all 869,085 vignettes taken with the UVP5 will be done in the home laboratory in order to reveal fine-scale distribution patterns of particles and zooplankton.

5.9 Expected Results

(Shipboard Scientific Party)

The work program of R/V METEOR cruise M189 was successfully completed. It allowed allowed us to maintain and enhance the ocean observing system off southwest Africa. Very high quality data of a suit of essential physical, biochemical and ecosystem ocean variables (e.g. sea surface and subsurface temperature and salinity, surface and subsurface currents, turbulent diapycnal fluxes, oxygen, nutrients, nitrous oxide, DIC, for details see https://goosocean.org/what-we-do/framework/essential-ocean-variables/) were collected in an oceanic region that has been sparsely sampled in the past. Due to the upwelling nature of the region, autonomous ocean observatories such as floats and drifters are quickly advected offshore such that the Global Ocean Observing System recommendation for special and temporal data coverage of essential ocean variable are not meet (e.g. Johns et al., 2021, Fig. 5.13). The collected data will thus contribute to improved data assimilation products used for a variety of purposes from local scientific studies to global ocean state reporting.

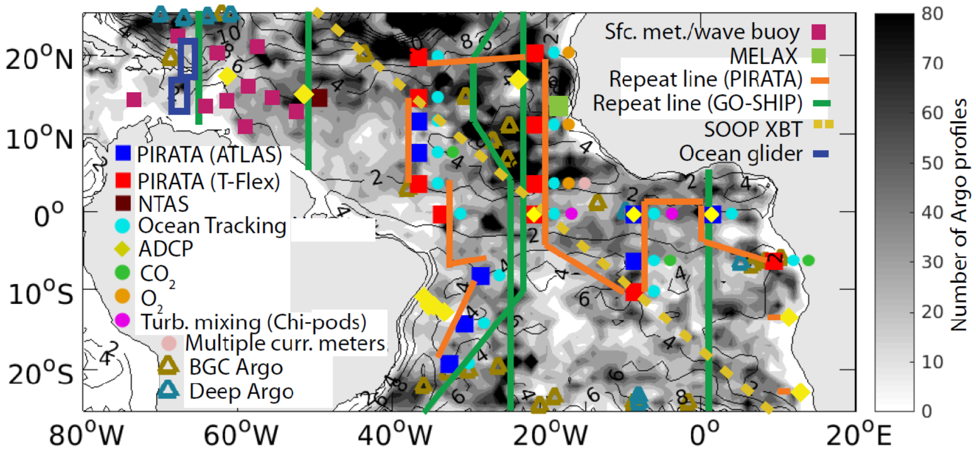

Fig. 5.13 Key elements of the tropical Atlantic in situ observing system. Gray shading represents the number of Argo profiles made in each 1° box between 2008 and 2017. Contours show the average number of hourly surface drifter observations made in each 1° box per month during 2008-2017 (from Johns et al., 2021).

Apart from this general result, the data collected during the cruise will allow us to address the all scientific aims described in section 3.2. In particular, the data sets collected during the two coastal process studies (Fig. 3.2) will allow a better understanding of the physical processes relevant to the upwelling off Angola through comparison with data sets from previous cruises

(M120, M131, and M148). This process understanding is important to advance Earth system model development to improve climate forecasts for the southeastern tropical Atlantic region. To date, Earth system models exhibit large warm biases in the southeastern tropical Atlantic that hamper reliable predictions of local future climate variability and change (e.g. Farneti et al., 2022).

Similarly, process understanding related to the formation pathways and air-sea fluxes of trace gases will be gained from the biochemical data that will allow advanced estimates of the in-situ production and emission of climate-relevant trace gases. Advances in this context are pivotal for a better understanding of potential responses of the ocean and the overlying atmosphere to environmental changes such as warming and deoxygenation.

6 Ship's Meteorological Station

(A. Elsässer, F. Otte)

R/V METEOR left the port of Walvis Bay, Namibia on April 16, 2023 at 09:30 in the morning for expedition M189-1. The cruising area for the first few days was influenced by a high-pressure area west of Cape Town and a trough along the African coast. In fair weather with moderate visibility and light southerly winds of 2-3 Bft and a significant wave height of 2-3 m, the research work could be started as planned.

From April 19, 2023, the significant wave height decreased to 1.5 to 2 m with moderate winds around 4 Bft. Due to increasing air pressure gradients between the trough and the high over South Africa, the wind freshened in the following 2 days. At times, 7 Bft with gusts up to 8 Bft were measured. The significant wave height was 3 m with a swell from southern directions.

While the high-pressure area west of Cape Town was pushed westwards by low- pressure areas over the southern Atlantic, a stable high-pressure area was able to become established on the west coast of Brazil. This formed a high-pressure bridge between Brazil and the southwest African coast from April 22. The trough along the Angolan coast weakened and thus the high-pressure weather determined the next days in the working area. This resulted in southerly winds of 3 to 4 Bft and a significant wave height of 2.5 m with a swell from south-southwest. This decreased to 1.5 m in the following days during the transit back to Walvis Bay. There, the cruise was briefly interrupted to take on research equipment.

Under the influence of a cold front that passed through in the night of April 24, R/V METEOR reached the port of Walvis Bay at noon time in clear and sunny weather. The wind continued to blow from the south at 4 to 5 Bft and the significant sea height from the south decreased to 1 m. Under these conditions, R/V METEOR left the harbour in the evening, heading for the research area off the Angolan coast.

During the transit in the following 3 days, the southerly wind initially increased somewhat under trough influence along the coast of Namibia and Angola. Gusts of up to 6 Bft were measured. The significant wave height increased up to 2.5 m with swells from the south.

From April 28, R/V METEOR, in transit to the working area, entered the centre of the trough along the African coast. This resulted in light winds from south to southwest at 2 to 3 Bft and a significant wave height of 1.5 m from southwest. These weather conditions essentially persisted in the following working areas further south. However, at noon on May 5, there was a brief increase in wind speed to 6 Bft from North to Northwest off Porto Amboim, Angola. This was caused by a strong thunderstorm cell north of the working area and lasted until the afternoon.

Only when the new research area was reached on 09/05/2023 near the border between Angola and Namibia, did the weather conditions change slightly. The wind from south increased to 4 Bft with a significant sea wave height of 2.5 m. The swell came from south-southwest. In these weather conditions, the research work was successfully completed and in the morning of May 10, R/V METEOR left the last working area and headed back to the port of departure.

On the last leg to Walvis Bay, wind and swell gradually increased and peaked at 5 to 6 Bft, with gusts of 7 Bft with 3.5 m significant wave height on arrival. On May 12, R/V METEOR reached the port of Walvis Bay at about noon.

7 Station List M189/1

7.1 Overall Station List

Station No.		**Date**	**Gear**	**Time**	**Latitude**	**Longitude**	**Depth**	**Remarks**
METEOR	**GEOMAR**	**2023**		**[UTC]**	**[°S]**	**[°E]**	**[m]**	
M189_01-1	CTD 1	16.04.	CTD	14:12	22° 59.963'	013° 29.968'	240	
M189_02-1	Drifter 1	16.04.	Drifter	16:00	23° 00.270'	013° 31.894'	205	IOW drifter deployment
M189_03-1	CTD 2	16.04.	CTD	17:08	22° 59.941'	013° 37.889'	151	
M189_04-1	MSS 1	16.04.	MSS	17:36	23° 00.038'	013° 37.687'	151	
M189_05-1	CTD 3	16.04.	CTD	19:58	23° 00.074'	013° 42.436'	153	
M189_06-1	MSS 2	16.04.	MSS	20:28	22° 59.670'	013° 42.525'	151	
M189_07-1	CTD 4	16.04.	CTD	22:37	22° 59.930'	013° 47.909'	149	
M189_08-1	MSS 3	16.04.	MSS	23:02	22° 59.926'	013° 47.857'	148	
M189_09-1	CTD 5	17.04.	CTD	00:32	22° 59.971'	013° 52.988'	147	
M189_10-1	MSS 4	17.04.	MSS	00:54	23° 00.006'	013° 52.982'	147	
M189_11-1	CTD 6	17.04.	CTD	02:21	22° 59.993'	013° 58.111'	142	
M189_12-1	MSS 5	17.04.	MSS	02:43	23° 00.108'	013° 58.177'	143	
M189_13-1	CTD 7	17.04.	CTD	04:39	23° 02.049'	014° 03.133'	135	
M189_14-1	MSS 6	17.04.	MSS	04:59	23° 02.143'	014° 03.241'	135	
M189_15-1	CTD 8	17.04.	CTD	06:36	22° 59.863'	014° 08.018'	133	
M189_16-1	MSS 7	17.04.	MSS	07:05	22° 59.969'	014° 08.013'	125	
M189_17-1	CTD 9	17.04.	CTD	08:37	22° 59.948'	014° 13.050'	111	
M189_18-1	MSS 8	17.04.	MSS	08:50	22° 59.854'	014° 13.049'	111	
M189_19-1	CTD 10	17.04.	CTD	10:20	22° 59.970'	014° 18.038'	0	
M189_20-1	MSS 9	17.04.	MSS	10:37	23° 00.014'	014° 18.042'	84	
M189_21-1	Mooring 1	17.04.	Mooring	12:39-14:12	22° 59.679'	014° 03.393'	138	LTMB mooring recovery
M189_22-1	Mooring 2	17.04.	Mooring	14:36-16:05	23° 01.235'	014° 01.989'	136	recovery of sediment trap
M189_23-1	CTD 11	17.04.	CTD	19:42	22° 59.950'	013° 29.931'	240	
M189_24-1	MSS 10	17.04.	MSS	20:03	22° 59.968'	013° 30.041'	238	
M189_25-1	CTD 12	17.04.	CTD	22:19	22° 59.945'	013° 19.972'	355	
M189_26-1	MSS 11	17.04.	MSS	22:48	22° 59.924'	013° 19.853'	355	
M189_27-1	CTD 13	18.04.	CTD	00:56	23° 00.036'	013° 09.909'	326	
M189_28-1	MSS 12	18.04.	MSS	01:18	23° 00.090'	013° 09.761'	324	
M189_29-1	CTD 14	18.04.	CTD	03:33	23° 00.068'	012° 59.806'	510	
M189_30-1	MSS 13	18.04.	MSS	03:59	23° 00.260'	012° 59.753'	515	
M189_31-1	CTD 15	18.04.	CTD	06:44	23° 00.370'	012° 45.241'	1015	
M189_32-1	MSS 14	18.04.	MSS	07:14	23° 00.517'	012° 45.660'	1001	
M189_33-1	CTD 16	18.04.	CTD	10:20	23° 00.151'	012° 29.706'	1646	
M189_34-1	MSS 15	18.04.	MSS	11:50	23° 00.545'	012° 29.891'	1638	
M189_35-1	CTD 17	18.04.	CTD	15:07	23° 00.044'	012° 15.205'	2273	
M189_36-1	MSS 16	18.04.	MSS	16:14	23° 00.227'	012° 15.543'	2253	
M189_37-1	CTD 18	18.04.	CTD	19:31	23° 00.193'	011° 59.983'	2703	
M189_38-1	MSS 17	18.04.	MSS	20:35	23° 00.621'	012° 00.338'	2690	
M189_39-1	CTD 19	19.04.	CTD	00:08	23° 00.000'	011° 44.996'	2986	
M189_40-1	MSS 18	19.04.	MSS	01:10	23° 00.002'	011° 45.025'	2983	
M189_41-1	Drifter 2	19.04.	Drifter	11:47	23° 08.146'	013° 23.902'	319	IOW drifter recovery
M189_42-1	Mooring 3	19.04.	Mooring	15:51-16:25	22° 59.343'	014° 03.062'	136	LTMB mooring deployment (29)

M189_43-1	Mooring 4	19.04.	Mooring	16:53-17:32	23° 01.362'	014° 02.181'	140	sediment trap deployment
M189_44-1	CTD 20	19.04.	CTD	19:09	23° 00.003'	013° 57.971'	141	
M189_45-1	CTD 21	19.04.	CTD	21:48	22° 59.984'	014° 22.067'	36	
M189_46-1	CTD 22	19.04.	CTD	21:39	22° 59.956'	014° 22.100'	36	
M189_47-1	MSS 19	19.04.	MSS	21:59	22° 59.933'	014° 22.168'	37	
M189_48-1	Drifter 3	20.04.	Drifter	17:02	20° 25.372'	012° 39.485'	205	IOW drifter deployment
M189_49-1	CTD 23	20.04.	CTD	18:06	20° 27.727'	012° 34.968'	265	
M189_50-1	MSS 20	20.04.	MSS	18:25	20° 27.897'	012° 34.925'	267	
M189_51-1	CTD 24	20.04.	CTD	20:09	20° 30.207'	012° 29.982'	295	
M189_52-1	MSS 21	20.04.	MSS	20:22	20° 30.313'	012° 30.012'	295	
M189_53-1	CTD 25	20.04.	CTD	21:43	20° 33.875'	012° 22.564'	309	
M189_54-1	MSS 22	20.04.	MSS	21:56	20° 33.875'	012° 22.600'	309	
M189_55-1	CTD 26	20.04.	CTD	23:10	20° 37.476'	012° 15.036'	366	
M189_56-1	MSS 23	20.04.	MSS	23:33	20° 37.700'	012° 15.093'	369	
M189_57-1	CTD 27	21.04.	CTD	01:33	20° 41.225'	012° 07.501'	574	
M189_58-1	MSS 24	21.04.	MSS	01:55	20° 41.313'	012° 07.555'	570	
M189_59-1	CTD 28	21.04.	CTD	03:42	20° 45.061'	012° 00.072'	780	
M189_60-1	MSS 25	21.04.	MSS	04:10	20° 45.496'	012° 00.034'	787	
M189_61-1	CTD 29	21.04.	CTD	05:43	20° 50.052'	011° 49.932'	1101	
M189_62-1	MSS 26	21.04.	MSS	06:14	20° 50.352'	011° 49.950'	1105	
M189_63-1	CTD 30	21.04.	CTD	08:08	20° 55.002'	011° 40.133'	1419	
M189_64-1	MSS 27	21.04.	MSS	08:50	20° 55.419'	011° 40.374'	1414	
M189_65-1	CTD 31	21.04.	CTD	11:36	20° 59.990'	011° 29.973'	1894	
M189_66-1	MSS 28	21.04.	MSS	12:24	21° 00.151'	011° 30.017'	1895	
M189_67-1	MSS 29	21.04.	MSS	15:31	20° 50.138'	011° 49.972'	1100	
M189_68-1	MSS 30	21.04.	MSS	17:31	20° 45.039'	011° 59.991'	781	
M189_69-1	MSS 31	21.04.	MSS	19:24	20° 41.392'	012° 07.846'	564	
M189_70-1	MSS 32	21.04.	MSS	21:03	20° 37.651'	012° 15.007'	369	
M189_71-1	MSS 33	21.04.	MSS	22:49	20° 33.654'	012° 22.501'	309	
M189_72-1	MSS 34	22.04.	MSS	00:28	20° 29.999'	012° 29.987'	295	
M189_73-1	MSS 35	22.04.	MSS	01:50	20° 27.529'	012° 34.984'	266	
M189_74-1	CTD 32	22.04.	CTD	10:32	20° 25.017'	012° 40.008'	174	
M189_75-1	MSS 36	22.04.	MSS	10:48	20° 25.187'	012° 39.988'	192	
M189_76-1	CTD 33	22.04.	CTD	12:25	20° 22.489'	012° 44.983'	147	
M189_77-1	MSS 37	22.04.	MSS	12:37	20° 22.558'	012° 45.019'	146	
M189_78-1	CTD 34	22.04.	CTD	14:05	20° 20.018'	012° 49.994'	132	
M189_79-1	MSS 38	22.04.	MSS	14:22	20° 20.056'	012° 49.998'	132	
M189_80-1	CTD 35	22.04.	CTD	15:48	20° 17.515'	012° 54.974'	122	
M189_81-1	MSS 39	22.04.	MSS	16:00	20° 17.515'	012° 55.035'	121	
M189_82-1	CTD 36	22.04.	CTD	17:25	20° 15.009'	012° 59.967'	98	
M189_83-1	MSS 40	22.04.	MSS	17:46	20° 15.201'	013° 00.069'	98	
M189_84-1	MSS 41	22.04.	MSS	20:59	20° 15.320'	012° 32.704'	199	
M189_85-1	MSS 42	22.04.	MSS	23:12	20° 14.655'	012° 32.112'	201	
M189_86-1	MSS 43	23.04.	MSS	01:50	20° 13.875'	012° 32.784'	183	
M189_87-1	MSS 44	23.04.	MSS	05:54	20° 12.778'	012° 32.790'	173	
M189_88-1	MSS 45	23.04.	MSS	09:21	20° 12.876'	012° 32.938'	169	
M189_89-1	Drifter 4	23.04.	Drifter	11:44	20° 14.717'	012° 32.171'	201	IOW drifter recovery
M189_90-1	CTD 37	23.04.	CTD	18:27	20° 59.882'	013° 18.930'	99	
M189_91-1	CTD 38	24.04.	CTD	01:14	22° 00.065'	013° 46.996'	104	
M189_92-1	CTD 39	24.04.	CTD	07:00	22° 40.046'	014° 13.255'	101	
M189_93-1	MVP 1	26.04.	MVP	14:37-16:50	16° 44.401'	010° 29.990'	3216	
M189_94-1	MVP 2	26.04.	MVP	16:55-18:47	16° 29.105'	010° 29.998'	3223	
M189_95-1	CTD 40	26.04.	CTD	19:33	16° 15.203'	010° 29.804'	3553	
M189_96-1	MVP 3	26.04.	MVP	20:20-22:37	16° 15.377'	010° 29.806'	3552	
M189_97-1	MVP 4	26.04.	MVP	22:43-00:47	15° 59.006'	010° 30.000'	3606	
M189_98-1	CTD 41	27.04.	CTD	01:23	15° 44.817'	010° 29.888'	3576	
M189_99-1	MVP 5	27.04.	MVP	02:05-04:17	15° 44.532'	010° 29.995'	3575	
M189_100-1	MVP 6	27.04.	MVP	04:20-06:17	15° 28.745'	010° 29.997'	3355	
M189_101-1	CTD 42	27.04.	CTD	07:02	15° 15.105'	010° 29.944'	3460	
M189_102-1	MVP 7	27.04.	MVP	07:51-09:47	15° 14.000'	010° 30.000'	3497	
M189_103-1	MVP 8	27.04.	MVP	09:47-12:06	15° 00.450'	010° 29.997'	3514	
M189_104-1	MVP 9	27.04.	MVP	12:15-14:26	14° 44.176'	010° 29.998'	3610	
M189_105-1	CTD 43	28.04.	CTD	15:01	11° 04.834'	012° 37.954'	1534	

M189_106-1	MSS 46	28.04.	MSS	15:48	11° 05.520'	012° 37.963'	1560	
M189_107-1	CTD 44	28.04.	CTD	18:19	11° 00.232'	012° 44.065'	1426	
M189_108-1	MSS 47	28.04.	MSS	18:56	11° 00.463'	012° 44.181'	1432	
M189_109-1	CTD 45	28.04.	CTD	21:17	10° 56.092'	012° 50.934'	1366	
M189_110-1	MSS 48	28.04.	MSS	21:47	10° 56.351'	012° 50.856'	1370	
M189_111-1	CTD 46	28.04.	CTD	23:54	10° 51.974'	012° 56.832'	1261	
M189_112-1	MSS 49	29.04.	MSS	00:25	10° 52.074'	012° 56.630'	1263	
M189_113-1	CTD 47	29.04.	CTD	03:04	10° 47.842'	013° 02.659'	1162	
M189_114-1	MSS 50	29.04.	MSS	03:36	10° 47.821'	013° 02.355'	1161	
M189_115-1	CTD 48	29.04.	CTD	05:34	10° 44.000'	013° 08.946'	701	
M189_116-1	MSS 51	29.04.	MSS	06:02	10° 44.066'	013° 08.661'	723	
M189_117-1	Glider 1	29.04.	Glider	07:38	10° 41.860'	013° 11.673'	448	ifm13 deployment
M189_118-1	Glider 2	29.04.	Glider	08:43	10° 41.424'	013° 10.732'	483	ifm14 deployment
M189_119-1	CTD 49	29.04.	CTD	09:27	10° 41.053'	013° 09.894'	517	
M189_120-1	MSS 52	29.04.	MSS	09:49	10° 40.654'	013° 09.931'	504	
M189_121-1	Glider 3	29.04.	Glider	11:42	10° 41.105'	013° 14.539'	302	ifm09 deployment
M189_122-1	MOOR 5	29.04.	Mooring	13:02	10° 41.710'	013° 17.179'	201	KPO 1273 deployment
M189_123-1	Drifter 1	29.04.	Drifter	13:07	10° 41.911'	013° 17.106'	209	Hereon drifter deployment
M189_124-1	SML 2	29.04.	Lander	14:30	10° 37.151'	013° 23.457'	100	KPO 1275 deployment
M189_125-1	Drifter 2	29.04.	Drifter	14:42	10° 37.124'	013° 23.507'	102	Hereon drifter deployment
M189_126-1	SML 1	29.04.	Lander	15:57	10° 33.082'	013° 30.630'	52	KPO 1274 deployment
M189_127-1	Drifter 3	29.04.	Drifter	16:03	10° 33.035'	013° 30.733'	51	Hereon drifter deployment
M189_128-1	CTD 50	29.04.	CTD	16:48	10° 27.910'	013° 31.913'	29	
M189_129-1	MSS 53	29.04.	MSS	16:59	10° 27.973'	013° 32.057'	28	
M189_130-1	CTD 51	29.04.	CTD	18:29	10° 30.005'	013° 29.294'	49	
M189_131-1	MSS 54	29.04.	MSS	18:40	10° 30.189'	013° 29.394'	49	
M189_132-1	CTD 52	29.04.	CTD	20:00	10° 31.781'	013° 26.375'	65	
M189_133-1	CTD 53	29.04.	CTD	21:01	10° 33.593'	013° 23.343'	93	
M189_134-1	MSS 55	29.04.	MSS	21:17	10° 33.559'	013° 23.271'	93	
M189_135-1	CTD 54	29.04.	CTD	22:59	10° 35.683'	013° 20.380'	112	
M189_136-1	MSS 56	29.04.	MSS	23:13	10° 35.563'	013° 20.356'	111	
M189_137-1	CTD 55	30.04.	CTD	00:40	10° 37.975'	013° 17.571'	132	
M189_138-1	MSS 57	30.04.	MSS	00:53	10° 38.035'	013° 17.384'	133	
M189_139-1	Drifter 4	30.04.	Drifter	02:42	10° 42.062'	013° 11.766'	450	Hereon drifter deployment
M189_140-1	CTD 56	01.05.	CTD	06:47	06° 12.569'	012° 05.733'	41	
M189_141-1	MSS 58	01.05.	MSS	06:57	06° 12.583'	012° 05.559'	41	
M189_142-1	CTD 57	01.05.	CTD	08:12	06° 14.775'	012° 00.004'	66	
M189_143-1	MSS 59	01.05.	MSS	08:31	06° 14.877'	012° 00.010'	66	
M189_144-1	CTD 58	01.05.	CTD	09:56	06° 16.626'	011° 53.966'	83	
M189_145-1	MSS 60	01.05.	MSS	10:11	06° 16.630'	011° 53.916'	83	
M189_146-1	CTD 59	01.05.	CTD	11:41	06° 18.606'	011° 47.932'	107	
M189_147-1	MSS 61	01.05.	MSS	11:51	06° 18.623'	011° 47.814'	108	
M189_148-1	CTD 60	01.05.	CTD	13:25	06° 20.220'	011° 41.777'	121	
M189_149-1	MSS 62	01.05.	MSS	13:37	06° 20.143'	011° 41.675'	121	
M189_150-1	CTD 61	01.05.	CTD	15:07	06° 22.250'	011° 35.898'	205	
M189_151-1	MSS 63	01.05.	MSS	15:21	06° 22.355'	011° 35.853'	207	
M189_152-1	CTD 62	01.05.	CTD	16:53	06° 24.175'	011° 29.799'	354	
M189_153-1	MSS 64	01.05.	MSS	17:14	06° 24.321'	011° 29.597'	358	
M189_154-1	CTD 63	01.05.	CTD	19:12	06° 26.635'	011° 22.492'	533	
M189_155-1	MSS 65	01.05.	MSS	19:32	06° 26.817'	011° 22.486'	534	
M189_156-1	CTD 64	01.05.	CTD	21:34	06° 29.169'	011° 14.856'	844	
M189_157-1	MSS 66	01.05.	MSS	22:03	06° 29.292'	011° 14.645'	854	
M189_158-1	CTD 65	02.05.	CTD	00:00	06° 31.582'	011° 07.317'	1136	
M189_159-1	MSS 67	02.05.	MSS	00:27	06° 31.688'	011° 07.204'	1138	
M189_160-1	CTD 66	02.05.	CTD	02:30	06° 34.244'	011° 00.137'	1441	
M189_161-1	MSS 68	02.05.	MSS	03:04	06° 34.650'	011° 00.228'	1441	
M189_162-1	CTD 67	02.05.	CTD	05:16	06° 36.441'	010° 52.425'	1672	
M189_163-1	MSS 69	02.05.	MSS	05:52	06° 36 473'	010° 52 266'	1670	
M189_164-1	MVP 10	02.05.	MVP	08:15-17:03	06° 37.119'	010° 51.455'	1710	
M189_165-1	CTD 68	03.05.	CTD	15:19	11° 30.325'	011° 59.988'	2552	
M189_166-1	MSS 70	03.05.	MSS	16:17	11° 30.706'	011° 59.663'	2529	
M189_167-1	CTD 69	03.05.	CTD	19:13	11° 22.700'	012° 10.957'	2423	
M189_168-1	MSS 71	03.05.	MSS	20:05	11° 22.981'	012° 10.712'	2514	
M189_169-1	CTD 70	03.05.	CTD	23:19	11° 14.930'	012° 22.496'	1876	

M189_170-1	MSS 72	04.05.	MSS	00:04	11° 14.815'	012° 22.564'	1854	
M189_171-1	CTD 71	04.05.	CTD	02:21	11° 09.729'	012° 29.867'	1603	
M189_172-1	MSS 73	04.05.	MSS	02:56	11° 09.459'	012° 29.705'	1614	
M189_173-1	CTD 72	04.05.	CTD	04:56	11° 06.996'	012° 33.897'	1496	
M189_174-1	MSS 74	04.05.	MSS	05:34	11° 06.927'	012° 33.921'	1493	
M189_175-1	CTD 73	04.05.	CTD	07:52	11° 02.070'	012° 41.663'	1457	
M189_176-1	MSS 75	04.05.	MSS	08:28	11° 02.000'	012° 41.308'	1468	
M189_177-1	CTD 74	04.05.	CTD	10:38	10° 57.627'	012° 47.649'	1384	
M189_178-1	MSS 76	04.05.	MSS	11:13	10° 57.225'	012° 47.304'	1382	
M189_179-1	CTD 75	04.05.	CTD	13:21	10° 53.821'	012° 53.822'	1337	
M189_180-1	Mooring 6	04.05.	Mooring	14:46	10° 50.264'	012° 59.632'	1234	KPO 1246 recovery
M189_181-1	Glider 4	04.05.	Glider	17:08	10° 50.823'	012° 59.498'	1250	ifm14 recovery
M189_182-1	CTD 76	04.05.	CTD	18:58	10° 45.482'	013° 05.755'	935	
M189_183-1	MSS 77	04.05.	MSS	19:25	10° 45.393'	013° 05.901'	927	
M189_184-1	MSS 78	04.05.	MSS	21:11	10° 39.830'	013° 14.757'	452	
M189_185-1	MSS 79	04.05.	MSS	23:18	10° 38.014'	013° 17.427'	259	
M189_186-1	MSS 80	05.05.	MSS	01:25	10° 35.940'	013° 20.270'	113	
M189_187-1	MSS 81	05.05.	MSS	03:10	10° 34.290'	013° 22.554'	98	
M189_188-1	MSS 82	05.05.	MSS	05:11	10° 32.472'	013° 25.042'	82	
M189_189-1	MSS 83	05.05.	MSS	06:37	10° 31.225'	013° 26.757'	61	
M189_190-1	MSS 84	05.05.	MSS	08:10	10° 29.968'	013° 28.483'	52	
M189_191-1	Drifter 5	05.05.	Drifter	11:24	10° 44.907'	013° 36.609'	69	Hereon recovery s/n 308
M189_192-1	MSS 85	05.05.	MSS	13:30	10° 27.946'	013° 31.949'	29	MSS from rubber boat
M189_193-1	MVP 11	05.05.	MVP	15:45-18:03	10° 27.527'	013° 32.534'	26	
M189_194-1	CTD 77	05.05.	CT5	18:21	10° 33.979'	013° 23.315'	94	
M189_195-1	MVP 12	05.05.	MVP	18:41-19:32	10° 34.344'	013° 23.225'	95	
M189_196-1	CTD 78	05.05.	CTD	19:39	10° 35.979'	013° 20.637'	111	
M189_197-1	MVP 13	05.05.	MVP	19:53-20:38	10° 35.939'	013° 20.972'	109	
M189_199-1	Glider 5	05.05.	Glider	21:30	10° 40.414'	013° 28.989'	91	ifm13 recovery
M189_198-1	MVP 14	06.05.	MVP	01:09-02:44	10° 35.932'	013° 20.550'	113	
M189_200-1	Glider 6	06.05.	Glider	11:40	10° 40.077'	013° 15.714'	200	ifm09 recovery
M189_201-1	CTD 79	06.05.	CTD	13:37	10° 45.900'	013° 06.000'	941	
M189_202-1	Mooring 7	06.05.	Mooring	17:17	10° 50.072'	013° 00.010'	1222	deployment KPO 1272
M189_203-1	CTD 80	06.05.	CTD	18:12	10° 50.925'	013° 01.074'	1208	
M189_204-1	MSS 86	06.05.	MSS	20:39	10° 40.022'	013° 14.659'	140	
M189_205-1	MSS 87	06.05.	MSS	22:51	10° 37.840'	013° 17.770'	126	
M189_206-1	MSS 88	06.05.	MSS	01:05	10° 36.130'	013° 20.222'	113	
M189_207-1	MSS 89	07.05.	MSS	03:15	10° 34.367'	013° 22.713'	98	
M189_208-1	MSS 90	07.05.	MSS	05:14	10° 32.920'	013° 24.783'	86	
M189_209-1	MSS 91	07.05.	MSS	06:05	10° 32.404'	013° 25.532'	80	
M189_210-1	SLM 1	07.05.	Lander	09:04	10° 32.971'	013° 30.694'	52	KPO 1274 recovery
M189_211-1	SLM 2	07.05.	Lander	10:46	10° 37.041'	013° 23.618'	100	KPO 1275 recovered
M189_212-1	Drifter 6	07.05.	Drifter	11:47	10° 35.725'	013° 22.294'	100	Hereon s/n 271 recovery
M189_213-1	Drifter 7	07.05.	Drifter	12:30	10° 34.403'	013° 21.497'	100	Hereon s/n 276 recovery
M189_214-1	Mooring 8	07.05.	Mooring	13:58	10° 41.647'	013° 17.196'	200	KPO 1273 recovered
M189_215-1	CTD 81	07.05.	CTD	22:46	11° 59.911'	013° 32.004'	101	
M189_216-1	CTD 82	08.05.	CTD	06:37	12° 59.969'	012° 48.029'	169	
M189_217-1	CTD 83	08.05.	CTD	14:09	14° 00.016'	012° 18.009'	122	
M189_218-1	CTD 84	08.05.	CTD	20:48	14° 59.839'	012° 06.012'	220	
M189_219-1	CTD 85	08.05.	CTD	03:50	15° 59.971'	011° 40.977'	72	
M189_220-1	CTD 86	09.05.	CTD	04:32	16° 00.035'	011° 37.893'	118	
M189_221-1	CTD 87	09.05.	CTD	05:30	16° 00.225'	011° 34.901'	812	
M189_222-1	CTD 88	09.05.	CTD	07:17	16° 00.339'	011° 30.125'	1212	
M189_223-1	CTD 89	09.05.	CTD	09:36	16° 00.182'	011° 20.819'	1707	
M189_224-1	CTD 90	09.05.	CTD	12:15	16° 00.050'	011° 06.034'	2560	
M189_225-1	CTD 91	09.05.	CTD	14:19	16° 00.159'	011° 06.400'	2548	
M189_226-1	CTD 92	09.05.	CTD	18:01	15° 59.978'	010° 47.973'	3158	
M189_227-1	MSS 92	09.05.	MSS	19:12	16° 00.232'	010° 47.744'	3175	MSS protective cage tests
M189_228-1	CTD 93	09.05.	CTD	00:20	16° 00.081'	010° 29.966'	3625	
M189_229-1	CTD 94	10.05.	CTD	04:42	15° 59.959'	009° 59.921'	4064	to 1000m depth

7.2 CTD Station List

Station No.	Profile Station No.	Date	Time	Latitude	Longitude	Max. Depth	Bottom	Comment
METEOR		2023	[UTC]	[°S]	[°E]	[m]	[m]	
M189_1-1	1	16.04.	14:04	22°59.957'	13°29.942'	233	240	
M189_3-1	2	16.04.	17:01	22°59.958'	13°37.860'	142	151	
M189_5-1	3	16.04.	19:37	23°00.029'	13°42.372'	146	151	
M189_7-1	4	16.04.	22:34	22°59.910'	13°47.899'	139	148	
M189_9-1	5	17.04.	00:27	22°59.969'	13°52.998'	136	147	
M189_11-1	6	17.04.	02:17	23°00.028'	13°58.117'	132	143	
M189_13-1	7	17.04.	04:34	23°02.078'	14°03.187'	124	138	
M189_15-1	8	17.04.	06:31	22°59.840'	14°08.021'	118	136	
M189_17-1	9	17.04.	08:28	22°59.933'	14°13.058'	103	113	
M189_19-1	10	17.04.	10:16	22°59.980'	14°18.038'	73		
M189_23-1	11	17.04.	19:37	22°59.924'	13°29.954'	234	239	
M189_25-1	12	17.04.	22:14	22°59.935'	13°19.914'	344	355	
M189_27-1	13	18.04.	00:54	23°00.028'	13°09.829'	315	326	
M189_29-1	14	18.04.	03:28	23°00.150'	12°59.765'	500	511	
M189_31-1	15	18.04.	06:38	23°00.434'	12°45.499'	1002	1019	
M189_33-1	16	18.04.	10:16	23°00.274'	12°29.870'	1616	1646	
M189_35-1	17	18.04.	15:03	23°00.179'	12°15.522'	2269	2285	No SUNA
M189_37-1	18	18.04.	19:22	23°00.190'	12°00.198'	2687	2702	No SUNA
M189_39-1	19	19.04.	00:04	22°59.992'	11°45.020'	2974	2986	No SUNA
M189_44-1	20	19.04.	17:55	23°01.000'	14°02.731'	125	136	No SUNA
M189_45-1	21	19.04.	19:02	23°00.007'	13°57.977'	135	142	No SUNA
M189_46-1	22	19.04.	21:39	22°59.956'	14°22.100'	37		
M189_49-1	23	20.04.	18:02	20°27.755'	12°34.946'	257	266	
M189_51-1	24	20.04.	20:05	20°30.254'	12°29.975'	288	295	
M189_53-1	25	20.04.	21:37	20°33.790'	12°22.594'	302	309	
M189_55-1	26	20.04.	23:08	20°37.480'	12°15.042'	356	367	
M189_57-1	27	21.04.	01:29	20°41.207'	12°07.504'	559	570	
M189_59-1	28	21.04.	03:39	20°45.113'	12°00.128'	769	780	
M189_61-1	29	21.04.	05:39	20°50.068'	11°49.944'	1088	1101	
M189_63-1	30	21.04.	08:01	20°55.088'	11°40.254'	1409	1419	
M189_65-1	31	21.04.	11:28	20°59.994'	11°30.017'	1884	1894	
M189_74-1	32	22.04.	10:08	20°25.021'	12°40.006'	164	216	
M189_76-1	33	22.04.	12:20	20°22.492'	12°45.007'	136	146	
M189_78-1	34	22.04.	14:02	20°20.026'	12°50.009'	123	132	
M189_80-1	35	22.04.	15:45	20°17.519'	12°54.992'	115	122	
M189_82-1	36	22.04.	17:23	20°15.030'	12°59.992'	91	99	
M189_90-1	37	23.04.	18:23	20°59.861'	13°18.943'	94	100	
M189_91-1	38	24.04.	01:10	22°00.050'	13°46.975'	93	103	
M189_92-1	39	24.04.	06:54	22°40.033'	14°13.314'	88	100	
M189_95-1	40	26.04.	19:29	16°15.314'	10°29.711'	1201	3555	
M189_98-1	41	27.04.	01:19	15°44.818'	10°29.825'	1201	3577	
M189_101-1	42	27.04.	06:57	15°15.076'	10°30.066'	1202	3464	
M189_105-1	43	28.04.	14:59	11°05.102'	12°38.003'	1520	1538	
M189_107-1	44	28.04.	18:17	11°00.349'	12°44.228'	1419	1435	
M189_109-1	45	28.04.	21:13	10°56.228'	12°50.830'	1359	1368	
M189_111-1	46	28.04.	23:51	10°51.980'	12°56.731'	1250	1262	
M189_113-1	47	29.04.	03:01	10°47.766'	13°02.515'	1150	1162	
M189_115-1	48	29.04.	05:31	10°43.982'	13°08.852'	691	705	
M189_119-1	49	29.04.	09:24	10°40.896'	13°09.781'	496	519	
M189_128-1	50	29.04.	16:44	10°27.910'	13°31.928'	23	30	
M189_130-1	51	29.04.	18:25	10°30.005'	13°29.317'	43	50	
M189_132-1	52	29.04.	19:57	10°31.740'	13°26.417'	60	67	
M189_133-1	53	29.04.	20:56	10°33.526'	13°23.339'	88	93	
M189_135-1	54	29.04.	22:53	10°35.573'	13°20.382'	102	112	No SUNA
M189_137-1	55	30.04.	00:34	10°37.955'	13°17.543'	122	132	No SUNA
M189_140-1	56	01.05.	06:44	6°12.560'	12°05.699'	35	40	
M189_142-1	57	01.05.	08:09	6°14.748'	12°00.004'	60	65	

M189_144-1	58	01.05.	09:53	6°16.588'	11°53.936'	73	83	
M189_146-1	59	01.05.	11:36	6°18.601'	11°47.916'	99	108	
M189_148-1	60	01.05.	13:21	6°20.164'	11°41.729'	111	121	No SUNA
M189_150-1	61	01.05.	15:04	6°22.296'	11°35.881'	199	205	No SUNA
M189_152-1	62	01.05.	16:50	6°24.215'	11°29.718'	346	354	No SUNA
M189_154-1	63	01.05.	19:09	6°26.672'	11°22.489'	525	533	No SUNA
M189_156-1	64	01.05.	21:30	6°29.136'	11°14.665'	834	851	No SUNA
M189_158-1	65	01.05.	23:57	6°31.621'	11°07.235'	1121	1137	No SUNA
M189_160-1	66	02.05.	02:26	6°34.474'	11°00.203'	1434	1445	No SUNA
M189_162-1	67	02.05.	05:13	6°36.403'	10°52.332'	1656	1671	No SUNA
M189_165-1	68	03.05.	15:18	11°30.564'	11°59.754'	2547	2588	No SUNA
M189_167-1	69	03.05.	19:10	11°22.898'	12°10.858'	2395	2487	No SUNA
M189_169-1	70	03.05.	23:14	11°14.900'	12°22.535'	1863	1878	No SUNA
M189_171-1	71	04.05.	02:17	11°09.512'	12°29.734'	1595	1623	No SUNA
M189_173-1	72	04.05.	04:51	11°06.972'	12°33.914'	1482	1493	No SUNA
M189_175-1	73	04.05.	07:50	11°02.096'	12°41.400'	1441	1466	No SUNA
M189_177-1	74	04.05.	10:34	10°57.406'	12°47.381'	1371	1393	No SUNA
M189_179-1	75	04.05.	13:16	10°53.597'	12°53.670'	1320	1335	No SUNA
M189_182-1	76	04.05.	18:56	10°45.502'	13°05.791'	931	948	No SUNA
M189_194-1	77	05.05.	18:17	10°33.977'	13°23.350'	89	94	No SUNA
M189_196-1	78	05.05.	19:35	10°35.951'	13°20.663'	106	112	No SUNA
M189_201-1	79	06.05.	13:34	10°45.940'	13°05.975'	927	940	
M189_203-1	80	06.05.	18:08	10°50.878'	13°01.079'	1195	1208	
M189_215-1	81	07.05.	22:42	11°59.944'	13°32.008'	91	101	
M189_216-1	82	08.05.	06:33	12°59.966'	12°48.059'	166	202	
M189_217-1	83	08.05.	14:05	14°00.042'	12°17.993'	117	122	
M189_218-1	84	08.05.	20:45	14°59.857'	12°06.029'	217	218	
M189_219-1	85	09.05.	03:46	15°59.972'	11°40.981'	63	72	
M189_220-1	86	09.05.	04:27	16°00.070'	11°37.895'	110	118	
M189_221-1	87	09.05.	05:26	16°00.268'	11°34.862'	801	816	
M189_222-1	88	09.05.	07:15	16°00.350'	11°30.209'	1207	1278	
M189_223-1	89	09.05.	09:31	16°00.240'	11°20.659'	1689	1715	No SUNA
M189_224-1	90	09.05.	12:14	16°00.076'	11°06.190'	302	2556	No SUNA
M189_225-1	91	09.05.	14:14	16°00.203'	11°06.336'	2536	2553	No SUNA
M189_226-1	92	09.05.	17:58	15°59.971'	10°47.959'	3147	3160	No SUNA
M189_228-1	93	10.05.	00:13	15°59.956'	10°30.013'	3611	3624	No SUNA
M189_229-1	94	10.05.	04:38	15°59.986'	9°59.915'	1001	4063	No SUNA

7.3 Drifter and Float Deployments

7.3.1 HEREON Drifter Deployments

Station No.	Buoy ID	Date	Time	Latitude	Longitude	Water Depth
METEOR		2023	(UTC)	[°S]	[°E]	[m]
M189_125-1	SN235	29.04	14:42	10° 37.17'	013° 23.49'	100
M189_127-1	SN236	29.04	16:03	10° 33.37'	013° 29.20'	50
M189_127-1	SN237	29.04	16:03	10° 33.37'	013° 29.20'	50
M189_123-1	SN271	29.04	13:07	10° 41.71'	013° 16.75'	200
M189_125-1	SN272	29.04	14:42	10° 37.17'	013° 23.49'	100
M189_139-1	SN273	30.04	02:42	10° 42.00'	013° 11.85'	430
M189_139-1	SN274	30.04	02:42	10° 42.00'	013° 11.85'	430
M189_139-1	SN275	30.04	02:42	10° 42.00'	013° 11.85'	430
M189_123-1	SN276	29.04	13:07	10° 41.71'	013° 16.75'	200
M189_127-1	SN277	29.04	16:03	10° 33.37'	013° 29.20'	50
M189_125-1	SN307	29.04	14:42	10° 37.17'	013° 23.49'	100
M189_123-1	SN308	29.04	13:07	10° 41.71'	013° 16.75'	200

7.3.2 HEREON Drifter Recoveries

Station No.	Buoy ID	Date	Time	Latitude	Longitude	Water Depth
METEOR		2023	(UTC)	[°S]	[°E]	[m]
M189_191-1	SN308	05.05	11:24	10° 44.907'	013° 36,609'	
M189_212-1	SN271	07.05	11:47	10° 35.725'	013° 22.294'	
M189_213-1	SN276	07.05	12:30	10° 34.403'	013° 21.497'	69

7.3.3 IOW Drifting Buoy Deployment and Recoveries

	Deployment			Recovery		
Station No.	Date and Time (UTC)	Latitude	Longitude	Date and Time (UTC)	Latitude	Longitude
METEOR	2023	[°S]	[°E]	2023	[°S]	[°E]
M189_02-1 / M189_41-1	16-Apr-16:00	23°00.270'	013°31.894'	19-Apr-11:47	23°08.146'	013°23.902'
M189_48-1 / M189_89-1	20-Apr-17:02	20°25.372'	012°39.485'	23-Apr-11:44	20°14.717'	012°32.171'

Details of drifting buoy deployment:

1st Drifting buoy deployment:					**Notes:**	**M189_D1**
Vessel:	Meteor		M189			
Deployed:	16-Apr		2023	16:00 (drop)		
Latitude:			23°	00.270'	S	
Longitude:			013°	31.894'	E	
Water depth:			205	Mag Var:	12.60°W	
Vessel:	Meteor		M189			
Recovered:	19-Apr		2023	11:47 on deck		
Latitude:			23°	08.146'	S	
Longitude:			013°	23.902'	E	
Water depth:			319	Mag Var:	12.76°W	
ID	**Depth**	**Instr. Type**		**sn**	**Start-up**	**Remarks**
		Xeos Rover		1063	X	Clean and complete record
	0	Spotter Wave buoy		30890C	X	Clean and complete record
	1	RBR SoloT		205451	X	Clean and complete record
	5	MicroCAT		0680	X	Clean and complete record
	5	MiniDot Oxygen Sensor		404767	X	Clean and complete record
	10	RBR Duet		213312	X	Clean and complete record
	15	RBR SoloT		205452	X	Clean and complete record
	20	RBR SoloT		205453	X	Clean and complete record
	25	RBR SoloT		205454	X	Clean and complete record
	30	MicroCAT		1208	X	Clean and complete record
	30	MiniDot Oxygen Sensor		426001	X	Clean and complete record
	35	RBR SoloT		213002	X	Clean and complete record
	40	RBR SoloT		213004	X	Clean and complete record
	48	WHADCP 600kHz		17378	X	Clean and complete record
	48	MicroCAT		1209	X	Clean and complete record
	48	MiniDot Oxygen Sensor		554579	X	Clean and complete record
	48	WHADCP 300kHz		24323	X	Destroyed due to flooding, data only for first 10h

2nd drifting buoy deployment:				**Notes:**	**M189_D2**
Vessel:	Meteor	M189			

Deployed:	20-Apr	2023	17:02 (drop)	
Latitude:		20°	25.372'	S
Longitude:		012°	39.485'	E
Water depth:		205	Mag Var:	10.20°W
Vessel:	Meteor	M189		
Recovered:	23-Apr	2023	11:44 on deck	
Latitude:		20°	14.717'	S
Longitude:		012°	32.171'	E
Water depth:		201	Mag Var:	10.06 °W

ID	Depth	Instr. Type	sn	Start-up	Remarks
		Xeos Rover	1063	X	Clean and complete record
	0	Spotter Wave buoy	30890C	X	Clean and complete record
	1	RBR SoloT	205451	X	Clean and complete record
	5	MicroCAT	0680	X	Clean and complete record
	5	MiniDot Oxygen Sensor	404767	X	Clean and complete record
	10	RBR Duet	213312	X	Clean and complete record
	15	RBR SoloT	205452	X	Clean and complete record
	20	RBR SoloT	205453	X	Clean and complete record
	25	RBR SoloT	205454	X	Clean and complete record
	30	MicroCAT	1208	X	Clean and complete record
	30	MiniDot Oxygen Sensor	426001	X	Clean and complete record
	35	RBR SoloT	213002	X	Clean and complete record
	40	RBR SoloT	213004	X	Clean and complete record
	48	WHADCP 600kHz	17378	X	Clean and complete record
	48	MicroCAT	1209	X	Clean and complete record
	48	MiniDot Oxygen Sensor	554579	X	Clean and complete record
	48	WHADCP 300kHz	154	X	Clean and complete record

7.4 List of Mooring Deployments and Recoveries

7.4.1. Long-Term Moorings

Mooring recovery: LTMB 28					**Notes:**
Vessel:	METEOR	M189			
Deployed:	17-Jan	2022	15:56		
Vessel:	MERIAN				
Recovered:	17-Apr	2023	13:52 on deck		
Default Lat:		23°	00.00’	S	
Default Lon:		014°	03.00’	E	
Water depth:		130	Mag Var:	12.54°W	

ID	Depth	Instr. Type	sn	Start-up	Remarks
	15	RBR soloT	100468		clean and complete record
	18	RBR soloT	100469		record stopped 28 Jan 2022
	21	RBR soloT	102696		clean and complete record
	25	FLNTUSB	12123		Data not yet recovered
	25	Microcat	11153		clean and complete record
	28	RBR soloT	102698		clean and complete record
	32	RBR soloT	102900		clean and complete record
	36	RBR soloT	102901		clean and complete record
	40	Microcat	22941		clean and complete record
	60	Microcat	22942		clean and complete record
	60	miniDOT	784		Record stopped 14 Aug 2022
	75	RBR duet TD	82517		clean and complete record
	90	Microcat	22946		clean and complete record
	90	miniDOT	785		Record stopped 03 Sep 2022
	105	RBR soloT	205449		clean and complete record

	115	RBR soloT	205450	clean and complete record
	120	WHADCP 300 kHz	154	clean and complete record
	123	NTUS	563	submersed in the mud
	123	Microcat	22969	submersed in the mud
	123	miniDOT	1280	submersed in the mud
	125	Releaser KUM	RE: 247031	EN: 263202 Dis: 263221
	128	Releaser KUM	RE: 633601	EN: 620717 Dis: 620734 At secondary position

Mooring deployment: LTMB 29						**Notes:**	
Vessel:	METEOR		M189				
Deployed:	19-04		2023	18:11 (drop)			
Vessel:							
Recovered:							
Lat main:			23°	00.047'	S		
Lon main:			14°	02.985'	E		
Lat secondary			23°	00.122'	S	Groundrope:	300 m
Lon secondary:			14°	02.994'	E		
Water depth:			130	Mag Var:	12.54°W		
ID	**Depth**	**Instr. Type**		**sn**	**Start-up**	**Remarks**	
	15	RBR soloT		205450	x		
	21	RBR duet TD		82554	X		
	28	RBR soloT		100468	X		
	40	Microcat		1206	X		
	60	Microcat		1210	X		
	60	miniDOT		612697	X		
	75	RBR duet TD		82555	X		
	90	Microcat		4277	x		
	90	miniDOT		817217	X		
	105	RBR soloT		76381	X		
	128	WHADCP 300 kHz		20394	X		
	128	Microcat		1277	X		
	128	miniDOT		989857	X		
	129	Releaser KUM		RE: 252231		EN: 275753 Dis: 275770	
	129	Releaser KUM		RE: 225373		EN: 205272 Dis:205303 At secondary position	

Mooring recovery : NBUS WBST						**Notes:**	**EAST-11**
Vessel:	MERIAN		MSM105				
Deployed:	25-Jan		2022	02:47			
Vessel:	METEOR		M189				
Recovered:	17-Apr		2023	16:05 on deck			
Position Lat:			23°	01.399'	S		
Position Lon:			014°	02.230'	E		
Water depth:			139	Mag Var:	12.57°W		
ID	**Depth**	**Instr. Type**		**sn**	**Start-up**	**Remarks**	
	75	Hydrobios MST-12		311101		clean and complete record	
	75	MiniDot Oxygen Sensor		937245		clean and complete record	
	109	Benthos Release 866A		56041		EN: 4D Dis: 4B	

Mooring deployment: NBUS WBST					**Notes:**	**EAST-12**
Vessel:	METEOR		M189			
Deployed:	17-Apr		2023	17:32 (drop)		
Vessel:						

Recovered:						
Lat main:			23°	01.414'	S	
Lon main:			014°	02.234'	E	
Water depth:			140	Mag Var:	12.57°W	
ID	**Depth**	**Instr. Type**		**sn**	**Start-up**	**Remarks**
	75	Hydrobios MST-12		311101	X	
	75	MiniDot Oxygen Sensor		937245	X	
	109	Benthos Release 866A		56041		EN: 4D Dis: 4B

Mooring recovery PREFACE/SACUS Angola Array mooring					**Notes:**	**KPO_1246**
Vessel:	METEOR		M181			
Deployed:	24-Apr		2022	10:16		
Vessel:	METEOR		M189			
Recovered:	4-May		2023	14:46		
Latitude:			10°	50.05'	S	
Longitude:			12°	59.93'	E	
Water depth:			1229	Mag Var:	-3.615	
ID	**Depth**	**Instr. Type**		**s/n**	**Start-up Ready**	**Remarks**
KPO_1246_01	279	Argos Beacon		12616		
KPO_1246_02	304	Microcat /p		10706	**X**	clean and complete record
KPO_1246_03	304	Optode		939	**X**	clean and complete record
KPO_1246_04	502	Floatation		Flotec-3	**X**	
KPO_1246_05	502	ADCP LR 75 kHz up		12530	**X**	clean and complete record
KPO_1246_06	505	Microcat /p		10692	**X**	clean and complete record
KPO_1246_07	505	Optode		942	**X**	clean and complete record
KPO_1246_08	654	Aquadopp		P26209-3	**X**	clean and complete record
KPO_1246_09	704	Microcat		1682	**X**	clean and complete record
KPO_1246_10	850	Aquadopp		40893-9-260	**X**	clean and complete record
KPO_1246_11	951	Microcat		3753	**X**	clean and complete record
KPO_1246_12	1047	Aquadopp		40893-1-236	**X**	clean and complete record
KPO_1246_13	1207	Microcat/p		1719	**X**	clean and complete record
KPO_1246_14	1216	Release AR661		821		**Mode**:A **Enable**: 4AA7 **Release**:4AA8
KPO_1246_15	1216	Release AR861		1647	Code:	**Mode**:B **Enable**: 0A8C **Release**:0A55

Mooring deployment PREFACE/SACUS Angola Array mooring					**Notes:**	**KPO_1272**
Vessel:	METEOR		M189			
Deployed:	6-May		2023	17:17		
Vessel:						
Recovered:						
Latitude:			10°	50.07'	S	
Longitude:			13°	00.01'	E	
Water depth:			1230	Mag Var:	-3.537	
ID	**Depth**	**Instr. Type**		**s/n**	**Start-up ready**	**Remarks**
KPO_1272_01	277	Argos Beacon		12616		
KPO_1272_02	302	Microcat/p		10692	**X**	P (with Pressure sensor)
KPO_1272_03	302	Optode		1133	**X**	
KPO_1272_04	500	Floatation		Flotec-3	**X**	
KPO_1272_05	500	ADCP LR 75 kHz up		12530	**X**	
KPO_1272_06	502	Microcat		1682	**X**	
KPO_1272_07	502	Optode		1461	**X**	
KPO_1272_08	650	Aquadopp		40893-9-260	**X**	
KPO_1272_09	700	Microcat		2257	**X**	

KPO_1272_10	849	Aquadopp	26209-9	**X**		
KPO_1272_11	949	Microcat/p	3413	**X**		P (with Pressure sensor)
KPO_1272_12	1050	Aquadopp	40893-1-236	**X**		
KPO_1272_13	1206	Microcat/p	3411	**X**		P (with Pressure sensor)
KPO_1272_14	1216	Release AR661	821			**Mode**:A **Range**:4AA7 **Release**:4AA8
KPO_1272_15	1216	Release AR861	271		Code:	**Mode**:B **Range**: 1405 **Release**:1455

7.4.2. Short-Term Moorings

Mooring deployment and recovery: Short term mooring 200m						**Notes:**	**KPO_1273**
Vessel:	METEOR		M189				
Deployed:	29-Apr		2023	13:02			
Vessel:	METEORr		M189				
Recovered:	7-May		2023	13:55			
Latitude:			10°	41.710'	S		
Longitude:			013°	17.179'	E		
Water depth:			200	Mag Var:			
ID	**Depth**	**Instr. Type**		**s/n**	**Start-up**	**Remarks**	
KPO_1273_01	194.4	Flotation		J15225-004	x		
KPO_1273_02	194.4	Signature/p		200065	X		
KPO_1273_03	194.4	RBR-Duett /p		213312	X		
KPO_1273_04	200	Release RT661		34	Code: B	Enable: 5052 / Release: 5054	
KPO_1273_05	200	Release RT661		35	Code: B	Enable: B627 / Release: B629	

Mooring deployment and recovery: Lander SLM2 100m						**Notes:**	**KPO_1275**
Vessel:	METEOR		M189				
Deployed:	29-Apr		2023	14:30			
Vessel:	METEOR		M189				
Recovered:	7-May		2023	11:09			
Latitude:			10°	37.151'	S		
Longitude:			013°	23.457'	E		
Water depth:			100	Mag Var:			
ID	**Depth**	**Instr. Type**		**s/n**	**Start-up**	**Remarks**	
KPO_1275_01	100	Lander		SLM2	x		
KPO_1275_02	100	Microcat		IM 2255	X		
KPO_1275_03	100	WH-ADCP 300		14495	X	clean and complete record	
KPO_1275_04	100	Optode		0432	X		
KPO_1275_05	100	Lampe		896	X		
KPO_1275_06	100	Watchdog		116	X	Frequency 160, 725 MHz	
KPO_1275_07	100	Transducer		1012257-126763	Code:	Enable: 110072 / Release: 126763	

Mooring deployment and recovery: Lander SLM1 50m						**Notes:**	**KPO_1274**
Vessel:	METEOR		M189				
Deployed:	29-Apr		2023	15:56			
Vessel:	METEOR		M189				
Recovered:	7-May		2023	09:33			
Latitude:			10°	33.085'	S		
Longitude:			013°	30.626'	E		
Water depth:			50	Mag Var:			
ID	**Depth**	**Instr. Type**		**s/n**	**Start-up**	**Remarks**	
KPO_1274_01	50	Lander		SLM1	x		

KPO_1274_02	50	Microcat	2254	X	
KPO_1274_03	50	RBR-Duett	82517	X	
KPO_1274_04	50	WH-ADCP 600	12030	X	clean and complete record
KPO_1274_05	50	Optode	0381	X	
KPO_1274_06	50	Lampe	73	X	
KPO_1274_07	50	Watchdog	117	X	Frequency 160, 785 MHz
KPO_1274_08	50	Transducer	1806431-253136	Code:	Enable: 275506 / Release: 252136

7.5 List of Microstructure Stations

Station No. METEOR	Profile Station No.	Date	Time	Longitude [°S]	Latitude [°E]	No. of Profiles	File IDs	Remarks
M189_004_1	1	16.04.	17:36	23° 00.038'	013° 37.687'	3	001-003	
M189_006_1	2	16.04.	20:28	22° 59 670'	013° 42 525'	3	004-006	
M189_008_1	3	16.04.	23:02	22° 59 926’	013° 47 857'	3	007-009	
M189_010_1	4	17.04.	00:54	23° 00 006’	013° 52 982'	3	010-012	
M189_012_1	5	17.04.	02:43	23° 00 108’	013° 58 177'	3	013-015	
M189_014_1	6	17.04.	04:59	23° 02 143’	014° 03 241'	3	016-018	
M189_016_1	7	17.04.	07:05	22° 59 969'	014° 08 013'	3	019-021	
M189_018_1	8	17.04.	08:50	22° 59 854'	014° 13 049'	3	022-024	
M189_020_1	9	17.04.	10:37	23° 00 014'	014° 18 042'	3	025-027	caps not removed
M189_024_1	10	17.04.	20:03	22° 59 968'	013° 30 041'	3	028-030	
M189_026_1	11	17.04.	22:48	22° 59 924'	013° 19 853'	3	031-033	
M189_028_1	12	18.04.	01:18	23° 00 090'	013° 09 761'	3	034-036	
M189_030_1	13	18.04.	03:59	23° 00 260'	012° 59 753'	3	037-039	
M189_032_1	14	18.04.	07:14	23° 00 517'	012° 45 660'	3	040-042	
M189_034_1	15	18.04.	11:50	23° 00 545'	012° 29 891'	3	043-045	
M189_036_1	16	18.04.	16:14	23° 00 227'	012° 15 543'	3	046-048	
M189_038_1	17	18.04.	20:35	23° 00 621'	012° 00 338'	3	049-051	
M189_040_1	18	19.04.	01:10	23° 00 002'	011° 45 025'	0	n/a	cable broken
M189_047_1	19	19.04.	21:59	22° 59 933'	014° 22 168'	5	052-056	
M189_050_1	20	20.04.	18:25	20° 27 897'	012° 34 925'	1	057	cable problems
M189_052_1	21	20.04.	20:22	20° 30 313'	012° 30 012'	0	n/a	not deployed
M189_054_1	22	20.04.	21:56	20° 33 875'	012° 22 600'	0	n/a	not deployed
M189_056_1	23	20.04.	23:33	20° 37 700'	012° 15 093'	3	058-060	caps not removed
M189_058_1	24	21.04.	01:55	20° 41 313'	012° 07 555'	2	061-062	
M189_060_1	25	21.04.	04:10	20° 45 496'	012° 00 034'	0	n/a	not deployed
M189_062_1	26	21.04.	06:14	20° 50 352'	011° 49 950'	0	n/a	not deployed
M189_064_1	27	21.04.	08:50	20° 55 419'	011° 40 374'	3	063-065	
M189_066_1	28	21.04.	12:24	21° 00 151'	011° 30 017'	3	066-068	
M189_067_1	29	21.04.	15:31	20° 50 138'	011° 49 972'	3	069-071	
M189_068_1	30	21.04.	17:31	20° 45 039'	011° 59 991'	3	072-074	
M189_069_1	31	21.04.	19:24	20° 41 392'	012° 07 846'	3	075-077	
M189_070_1	32	21.04.	21:03	20° 37 651'	012° 15 007'	3	078-080	
M189_071_1	33	21.04.	22:49	20° 33 654'	012° 22 501'	3	081-083	
M189_072_1	34	22.04.	00:28	20° 29 999'	012° 29 987'	3	084-086	
M189_073_1	35	22.04.	01:50	20° 27 529'	012° 34 984'	3	087-089	
M189_075_1	36	22.04.	10:48	20° 25 187'	012° 39 988'	3	090-092	
M189_077_1	37	22.04.	12:37	20° 22 558'	012° 45 019'	3	093-095	
M189_079_1	38	22.04.	14:22	20° 20 056'	012° 49 998'	3	096-098	
M189_081_1	39	22.04.	16:00	20° 17 515'	012° 55 035'	3	099-101	
M189_083_1	40	22.04.	17:46	20° 15 201'	013° 00 069'	3	102-104	
M189_084_1	41	22.04.	20:59	20° 15 320'	012° 32 704'	7	105-111	
M189_085_1	42	22.04.	23:12	20° 14 655'	012° 32 112'	10	112-121	
M189_086_1	43	23.04.	01:50	20° 13 875'	012° 32 784'	18	122-140	Raw data file 139 does not exist
M189_087_1	44	23.04.	05:54	20° 12 778'	012° 32 790'	15	141-155	
M189_088_1	45	23.04.	09:21	20° 12 876'	012° 32 938'	8	156-163	

M189_106_1	46	28.04.	15:48	11° 05 520'	012° 37 963'	3	164-166	
M189_108_1	47	28.04.	18:56	11° 00 463'	012° 44 181'	3	167-169	
M189_110_1	48	28.04.	21:47	10° 56 351'	012° 50 856'	3	170-172	
M189_112_1	49	29.04.	00:25	10° 52 074'	012° 56 630'	3	173-175	
M189_114_1	50	29.04.	03:36	10° 47 821'	013° 02 355'	3	176-178	
M189_116_1	51	29.04.	06:02	10° 44 066'	013° 08 661'	3	179-181	
M189_120_1	52	29.04.	09:49	10° 40 654'	013° 09 931'	3	182-184	
M189_129_1	53	29.04.	16:59	10° 27 973'	013° 32 057'	20	185-204	
M189_131_1	54	29.04.	18:40	10° 30 189'	013° 29 394'	10	205-214	
M189_134_1	55	29.04.	21:17	10° 33 559'	013° 23 271'	9	215-223	
M189_136_1	56	29.04.	23:13	10° 35 563'	013° 20 356'	6	224-229	
M189_138_1	57	30.04.	00:53	10° 38 035'	013° 17 384'	6	230-235	
M189_141_1	58	01.05.	06:57	06° 12 583'	012° 05 559'	5	237-241	
M189_143_1	59	01.05.	08:31	06° 14 877'	012° 00 010'	5	242-246	
M189_145_1	60	01.05.	10:11	06° 16 630'	011° 53 916'	5	247-251	
M189_147_1	61	01.05.	11:51	06° 18 623'	011° 47 814'	5	252-256	
M189_149_1	62	01.05.	13:37	06° 20 143'	011° 41 675'	4	257-260	
M189_151_1	63	01.05.	15:21	06° 22 355'	011° 35 853'	3	261-263	
M189_153_1	64	01.05.	17:14	06° 24 321'	011° 29 597'	3	264-266	
M189_155_1	65	01.05.	19:32	06° 26 817'	011° 22 486'	3	267-269	
M189_157_1	66	01.05.	22:03	06° 29 292'	011° 14 645'	3	270-272	
M189_159_1	67	02.05.	00:27	06° 31 688'	011° 07 204'	3	273-275	
M189_161_1	68	02.05.	03:04	06° 34 650'	011° 00 228'	3	276-278	
M189_163_1	69	02.05.	05:52	06° 36 473'	010° 52 266'	3	279-281	
M189_166_1	70	03.05.	16:17	11° 30 706'	011° 59 663'	2	282-283	cable problems
M189_168_1	71	03.05.	20:05	11° 22 981'	012° 10 712'	3	284-286	
M189_170_1	72	04.05.	00:04	11° 14 815'	012° 22 564'	3	287-289	
M189_172_1	73	04.05.	02:56	11° 09 459'	012° 29 705'	3	290-292	
M189_174_1	74	04.05.	05:34	11° 06 927'	012° 33 921'	3	293-295	
M189_176_1	75	04.05.	08:28	11° 02 000'	012° 41 308'	3	296-298	
M189_178_1	76	04.05.	11:13	10° 57 225'	012° 47 304'	3	299-301	
M189_183_1	77	04.05.	19:25	10° 45 393'	013° 05 901'	3	302-304	
M189_184_1	78	04.05.	21:11	10° 39 830'	013° 14 757'	11	305-315	
M189_185_1	79	04.05.	23:18	10° 38 014'	013° 17 427'	15	316-330	
M189_186_1	80	05.05.	01:25	10° 35 940'	013° 20 270'	15	331-345	
M189_187_1	81	05.05.	03:10	10° 34 290'	013° 22 554'	18	346-363	
M189_188_1	82	05.05.	05:11	10° 32 472'	013° 25 042'	11	364-374	
M189_189_1	83	05.05.	06:37	10° 31 225'	013° 26 757'	20	375-394	
M189_190_1	84	05.05.	08:10	10° 29 968'	013° 28 483'	17	395-411	
M189_192_1	85	05.05.	13:30	10° 27 946'	013° 31 949'	(8)	n/a	from rubber boat
M189_204_1	86	06.05.	20:39	10° 40 022'	013° 14 659'	9	412-420	
M189_205_1	87	06.05.	22:51	10° 37 840'	013° 17 770'	15	421-435	
M189_206_1	88	07.05.	01:05	10° 36 130'	013° 20 222'	18	436-453	
M189_207_1	89	07.05.	03:15	10° 34 367'	013° 22 713'	21	454-474	
M189_208_1	90	07.05.	05:14	10° 32 920'	013° 24 783'	24	475-483	
M189_209_1	91	07.05.	06:05	10° 32,404'	013° 25,532'	15	483-498	
M189_227_1	92	09.05.	19:12	16° 02 068'	010° 45 779'	12	499-510	

7.6 List of N_2O and CH_4 Sampling Locations

Station No. METEOR	CTD profile	Latitude [°N]	Longitude [°E]	N_2O	CH_4
M189_1_1	1	-22.999	13.4995	x	x
M189_5_1	3	-23.0015	13.7084	x	x
M189_17_1	9	-22.9992	14.2172	x	x
M189_25_1	12	-22.9994	13.3329	x	
M189_42_1	20	-23.0161	14.0451	x	x
M189_46_1	22	-22.9999	14.3675	x	x
M189_51_1	24	-20.502	12.4992	x	

M189_55_1	26	-20.6247	12.2501	x	
M189_74_1	32	-20.4172	12.6665	x	x
M189_78_1	34	-20.3332	12.8329	x	x
M189_80_1	35	-20.2919	12.916	x	x
M189_82_1	36	-20.25	12.9991	x	x
M189_88_1	37	-20.9983	13.3153	x	x
M189_91_1	38	-22.001	13.7836	x	x
M189_92_1	39	-22.6677	14.22	x	x
M189_95_1	40	-16.2493	10.4979	x	
M189_98_1	41	-15.7471	10.499	x	
M189_101_1	42	-15.2506	10.499	x	
M189_105_1	43	-11.076	12.6321	x	
M189_109_1	45	-10.9331	12.8494	x	
M189_113_1	47	-10.7988	13.0478	x	
M189_115_1	48	-10.7333	13.15	x	
M189_119_1	49	-10.6879	13.1694	x	
M189_128_1	50	-10.4652	13.5316	x	x
M189_132_1	52	-10.53	13.4388	x	x
M189_137_1	55	-10.6333	13.2928	x	x
M189_140_1	56	-6.2096	12.0959	x	x
M189_148_1	60	-6.3384	11.6976	x	x
M189_152_1	62	-6.4023	11.4978	x	
M189_162_1	67	-6.6066	10.8751	x	
M189_194_1	77	-10.5663	13.3882	x	x
M189_196_1	78	-10.6	13.3435	x	
M189_215_1	81	-11.9981	13.5331	x	x
M189_216_1	82	-12.9996	12.8	x	x
M189_217_1	83	-0.25	12.3004	x	x
M189_218_1	84	-14.9982	12.1003	x	x
M189_219_1	85	-15.9994	11.6829	x	x
M189_220_1	86	-16.0005	11.6322	x	
M189_221_1	87	-15.9999	11.5819	x	
M189_222_1	88	-16.0019	11.4988	x	
M189_223_1	89	-16.0012	11.3486	x	
M189_225_1	91	-16.0016	11.1037	x	
M189_226_1	92	-15.9996	10.8004	x	
M189_229_1	94	-15.9996	9.9989	x	

8 Data and Sample Storage and Availability

In Kiel, a joint data management team is set up to store the data from various projects and cruises in a web-based multi-user-system. Data gathered during M198 are stored at the Kiel data portal, and remain proprietary for the PIs of the cruise and for members of EU-TRIATLAS and the BMBF-BANINO project. Each station is logged as an event file https://portal.geomar.de/metadata/leg/show/361075. All data will be submitted to PANGAEA within 3 years after the cruise, i.e. by May 2026. Some data sets are already made publicly available (Table 8.1). Preliminary CTD data were submitted to CORIOLIS during the cruise for real time oceanographic analysis and Argo calibration. Data availability and contact persons for the different datasets are listed in Table 8.1.

Table 8.1 Overview of data availability and contact persons. Data that are publicly available at the time the report was published are marked by green text in the free access column.

Data Type	Database	Access	Free Access	Contact Person
CTD/O_2	OSIS	https://osis.geomar.de/app/expeditions/361075/files	May 2026	G. Krahmann, GEOMAR, gkrahmann@geomar.de
VMADCP	PANGAEA	PANGAEA.962915 (38 kHz) PANGAEA.962916 (75 kHz)	**Oct. 2023**	R. Kopte, DAM, Kiel University, robert.kopte@ifg.uni-kiel.de
Moving vessel profiler data	OSIS	https://osis.geomar.de/app/expeditions/361075/files	May 2026	G. Krahmann, GEOMAR, gkrahmann@geomar.de
Long-term mooring data Angola (GEOMAR)	OSIS	https://osis.geomar.de/app/expeditions/361075/files	May 2026	P. Brandt, GEOMAR pbrandt@geomar.de
Short-term mooring data Angola (GEOMAR)	OSIS	https://osis.geomar.de/app/expeditions/361075/files	May 2026	M. Dengler, GEOMAR, mdengler@geomar.de
Long-term mooring data from Namibia (IOW)			May 2026	V. Mohrholz, IOW volker.mohrholz@io-warnemuende.de
Sediment trap data from Namibia			May 2026	N. Lahajnar, Hamburg University, niko.lahajnar@uni-hamburg.de
Hereon Drifter data	OSIS	https://osis.geomar.de/app/expeditions/361075/files	May 2026	M. Dengler, GEOMAR, mdengler@geomar.de
IOW drifter data			May 2026	V. Mohrholz, IOW volker.mohrholz@io-warnemuende.de
Shipboard microstructure data	OSIS	https://osis.geomar.de/app/expeditions/361075/files	May 2026	M. Dengler, GEOMAR, mdengler@geomar.de
Thermosalinograph	PANGAEA	https://doi.pangaea.de/10.1594/PANGAEA.968974	**March 2024**	M. Schlundt, DAM, GEOMAR, mschlundt@geomar.de
Glider data	OSIS	https://osis.geomar.de/app/expeditions/361075/files	May 2026	M. Dengler, GEOMAR, mdengler@geomar.de
X-Band radar data			May 2026	Jochen Horstmann, hereon, jochen.horstmann@hereon.de
Multibeam echosounder	PANGAEA	PANGAEA.965762	**April 2024**	M. Schumacher, GEOMAR mschumacher@geomar.de
Nutrients (nitrate, nitrite, H_2S)	OSIS	https://osis.geomar.de/app/expeditions/361075/files	May 2026	D. Arévalo-Martínez, RU damian.arevalomartinez@ru.nl
Trace gases (underway, water column)			May 2026	D. Arévalo-Martínez, RU damian.arevalomartinez@ru.nl
Underwater Vision Profiler			May 2026	R. Kiko, GEOMAR rkiko@geomar.de
Oxygen concentrations	OSIS	https://osis.geomar.de/app/expeditions/361075/files	May 2026	M. Dengler, GEOMAR, mdengler@geomar.de
Primary Productivity, POM, DIC, TA, DNA			May 2026	C. Löscher, SDU cloescher@biology.sdu.dk

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11 Abbreviations

ABFZ	Angola-Benguela Frontal Zone
AC	Angola Current
ADCP	Acoustic Doppler Current Profiler
BANINO	Benguela Niños: Physical Processes and Long-Term Variability
BCLME	Benguela Current Large Marine Ecosystem
Bft	Beaufort
BMBF	Federal Ministry of Education and Research
CTD	Conductivity-Temperature-Depth (system)
DAM	Deutsch Allianz Meeresforschung
DFG	German Science Foundation
DIC	Dissolved Inorganic Carbon
DNA	Deoxyribonucleic Acid
EEZ	Exclusive Economic Zone
EUC	Equatorial Undercurrent
GPF	Begutachtungspanel Forschungsschiffe
LTMB	Long-term mud belt
MSS	Microstructure System
MVP	Moving Vessel Profiler
nBUS	northern Benguela Upwelling System
OMZ	Oxygen Minimum Zones
OS38	38-kHz RDI Ocean Surveyor
OS75	75-kHz RDI Ocean Surveyor
POM	Particulate Organic Matter
PP	Primary Production
SACW	South Atlantic Central Water
sBUS	southern Benguela Upwelling System
SEC	South Equatorial Current
SEUC	South Equatorial Undercurrent
SST	Sea Surface temperature
tAUS	tropical Angolan Upwelling System
vmADCP	vessel-mounted Acoustic Doppler Current Profiler
TA	Total Alkalinity
TSG	Thermosalinograph
UVP	Underwater Vision Profiler