MARIA S. MERIAN-Berichte

WASCAL students meet science – Educating West-African students by Training-Through-Research

Cruise No. MSM106

26.02.2022 – 19.03.2022,

Mindelo (Cabo Verde) – Bremerhaven (Germany)

WASCAL

B. Fiedler, C. Almeida, H. Andresen, E. Borchert, T. Fischer, H. Fock, T. Hamm, H. Hauss, M. Schaber, T. Steinhoff, A. Pinck, N. Vieira, K. Walker

Dr. Björn Fiedler

GEOMAR Helmholtz Centre for Ocean Research Kiel

2022

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1 Summary

1.1 Summary in English

MARIA S. MERIAN Cruise MSM106 was conceptualized as a joint research and curricular education cruise. The training component of MSM106 was part of the curriculum of the international Master program "Climate Change and Marine Sciences", which is currently being implemented at Universiade Técnica do Atlãntico (UTA) in Cabo Verde within the framework of the BMBF-funded WASCAL program ("West African Science Service Centre on Climate Change and Adapted Land Use"). Students from 12 West African countries participated in this cruise. Several modules of the curriculum were taught theoretically and practically at sea. Throughout the cruise West African students got involved in the different research components of MSM106.

First, a mooring and an autonomous surface vehicle equipped with novel instrumentation for $p\mathrm{CO_2}$ analysis got deployed at Nola Seamount near the Cabo Verdean Island Santo Antao to carry out a 3-month long test deployment. After ADCP and hydroacoustic biomass surveys near the archipelago an anticyclonic mode-water eddy near CVOO was investigated intensively (incl. CTD section, biogeochemical & ecological samplings). A full time-series sampling was conducted at CVOO as well. After this, daily stations along the transit towards Germany were carried out. Off Canary Islands the ESTOC time-series site was sampled, followed by another eddy survey off Portugal main land. The daily station scheme was continued along the transit to Bremerhaven. Off the Rhine River delta an extended sampling for microplastics has been conducted.

1.2 Summary in German

Die MARIA S. MERIAN Expedition MSM106 wurde als gemeinsame Forschungs- und Ausbildungsreise konzipiert. Die Ausbildungskomponente von MSM106 war Teil des Lehrplans des internationalen Masterstudiengangs "Climate Change and Marine Sciences", der derzeit an der Universiade Técnica do Atlãntico (UTA) in Cabo Verde im Rahmen des vom BMBF geförderten WASCAL-Programms ("West African Science Service Centre on Climate Change and Adapted Land Use") durchgeführt wird. Studenten aus 12 westafrikanischen Ländern nahmen an dieser Reise teil. Mehrere Module des Lehrplans wurden theoretisch und praktisch auf See unterrichtet. Während der gesamten Fahrt wurden die westafrikanischen Studenten in die verschiedenen Forschungskomponenten von MSM106 eingebunden.

Zunächst wurden eine Verankerung und ein autonomes Oberflächenfahrzeug, das mit neuartigen Instrumenten für die $p\mathrm{CO_2}$-Analyse ausgestattet ist, am Nola Seamount in der Nähe der Cabo-Verde-Insel Santo Antao ausgesetzt, um einen dreimonatigen Testeinsatz durchzuführen. Nach ADCP- und hydroakustischen Biomassemessungen in der Nähe des Archipels wurde ein antizyklonaler Wasserwirbel in der Nähe von CVOO intensiv untersucht (inkl. CTD-Schnitt, biogeochemische und ökologische Proben). Auch bei CVOO wurde eine vollständige Zeitserienbeprobung durchgeführt. Danach wurden tägliche Stationen entlang des Transits nach Deutschland durchgeführt. Vor den Kanarischen Inseln wurde der ESTOC-Zeitreihenstandort beprobt, gefolgt von einer weiteren Wirbelbeprobung vor dem portugiesischen Festland. Das tägliche Stationsschema wurde auf dem Transit nach Bremerhaven fortgesetzt. Vor dem Rheindelta wurde abschließend eine erweiterte Probenahme für Mikroplastik durchgeführt.

2 Participants

2.1 Principal Investigators

Name	Institution
Fiedler, Björn, Dr.	GEOMAR
Almeida, Corrine, Prof.	UTA
Fischer, Tim, Dr.	GEOMAR
Hauss, Helena, Dr.	GEOMAR
Borchert, Erik, Dr.	GEOMAR
Fock, Heino, Dr.	vTI
Schaber, Matthias, Dr.	vTI

2.2 Cruise Participants

Name	Discipline	Institution	Leg
Fiedler, Björn, Dr.	Chemical Oceanogr. / Chief Scientist	GEOMAR	1 + 2
Almeida, Corrine, Prof.	Biological Oceanogr. / Chl-a analysis	UTA	1 + 2
Fischer, Tim, Dr.	Physical Oceanogr. / TSG+CTD+ADCP	GEOMAR	1 + 2
Pinck, Andreas, Dipl.-Ing.	Engineer / CTD + Mooring	GEOMAR	1
Hauss, Helena, Dr.	Biological Oceanogr. / Zooplankton	GEOMAR	1
Steinhoff, Tobias, Dr.	Chemical Oceangr. / Biogeochemistry	GEOMAR	1
Hamm, Thea	Biological Oceanogr. / Microplastics	GEOMAR	2
Borchert, Erik, Dr.	Biological Oceanogr. / Microplastics	GEOMAR	1
Kaehlert, Sarah	Communication officer / outreach	GEOMAR	2
Fock, Heino, Dr.	Biological Oceanogr. / Zooplankton	vTI	2
Schaber, Matthias, Dr.	Biological Oceanogr. / biomass hydroacoust.	vTI	1
Andresen, Henrike, Dr.	Biological Oceanogr. / biomass hydroacoust.	vTI	2
Vieira, Nuno	Biological Oceanogr. / oxygen analysis	IMAR/OSCM	1 + 2
Attannon, Degbe	Student	UTA	1 + 2
Kabore, Nongma	Student	UTA	1
Fernandes, Sandra	Student	UTA	1 + 2
Soro, Gilles	Student	UTA	1 + 2
Quaye, Daniel	Student	UTA	1 + 2
Konate, Djibril	Student	UTA	1 + 2
Idrissa, Samira	Student	UTA	1 + 2
Diouf, Gnilane	Student	UTA	1 + 2
Tora, Dkawlma	Student	UTA	1 + 2
Kujabie, Abubacarr	Student	UTA	1 + 2
Ndure, Melissa	Student	UTA	1 + 2
Oyikeke, Tolulope	Student	UTA	2

2.3 Participating Institutions

GEOMAR	GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany
UTA	Universidade Técnica do Atlântico, Mindelo, Cabo Verde
vTI	Thünen Institut für Seefischerei, Bremerhaven, Germany
IMAR	Instituto do Mar, Mindelo, Cabo Verde
OSCM	Ocean Science Centre Mindelo, Mindelo, Cabo Verde

3 Research Programme

3.1 Description of the Work Area

The main work area of cruise MSM106 includes the Eastern Tropical North Atlantic (ETNA) followed by a transit from this area all the way into the North Sea off Germany (Fig. 3.1). The key process in the ETNA region around Cabo Verde is the coastal upwelling system off Mauritania. This Eastern Boundary Upwelling System (EBUS) is one of the most productive upwelling regions in the world's oceans and as such hosts a rich and highly diverse ecosystem (Chavez and Messié 2009). The Mauritanian upwelling system shows a strong seasonal evolution due to variable strength of the NE trade winds. During winter months strong upwelling is being observed off the Mauritanian coast while during summer months upwelling diminishes due to less intense wind curl stress (Mittelstaedt 1991).

Furthermore, the ETNA hosts an eastern boundary Oxygen Minimum Zone (OMZ), which is primarily created from sluggish ventilation and high productivity in the EBUS along the West African coast. The vertical oxygen distribution shows two distinct oxygen minima, an upper one at about 75 m depth and a deep OMZ core at about 400 m (Stramma et al., 2008a). On the large scale, the minimum oxygen concentrations in the ETNA OMZ are just below 40 µmol kg^{-1} but an expansion of the OMZ, both in terms of intensity and vertical extent, has been observed over periods of decades (Stramma et al., 2008b). However, Karstensen et al. (2015) reported the appearance of very low oxygen concentrations at very shallow depth, close to the mixed layer base, within the ETNA. This was observed during a long-term oxygen time series from a mooring and profiling float at the Cape Verde Ocean Observatory (CVOO). By making use of satellite derived sea level anomaly data, the authors could associate the occurrence of the low oxygen events with cyclonic (CE), as well as anticyclone mode-water eddies (ACMEs). The latter ones are characterized by a water lens of mode which is being formed by up- and downward-bent isopycnals towards the eddy center. Normal anticyclones did not show any low oxygen signatures. They also propose that the oxygen minimum in CEs and ACMEs is not being exported from the eddy formation region (along the west African coast), but created during the westward passage of the eddies into the open ETNA.

3.2 Aims of the Cruise

Primary objective of this cruise was the academic education of students from the West African program WASCAL (West African Science Service Centre on Climate Change and Adapted Land Use) during an authentic research expedition. Therefore, theoretical lecture modules were combined with practical training sessions about classical oceanographic field-sampling methods (e.g., gear deployment/recovery, analytical lab techniques, data reduction and visualization, etc.). Scientific data obtained during the cruise have been used instantaneously for teaching and training purposes but also for scientific exploitation.
The following lecture modules of the MRP-CCMS curriculum were taught on board:

1) Ocean Observations
2) Hydroacoustics in fisheries and marine ecology
3) Communication and scientific writing

Besides teaching modules also research modules have been carried out in order to (i) contribute to current research efforts in the region and to global ocean observing programs, (ii) teach the students with state-of-the-art oceanographic technologies and real scientific data, and (iii) carry out dedicated surveys and collect scientific data for individual master thesis projects. Therefore, the following research modules have been an integral part of this cruise:

Module 1, *Surface ocean biogeochemistry*: Underway measurements of key surface properties (temperature, salinity, CO_2 partial pressure, O_2 partial pressure, total gas tension, chlorophyll, turbidity) that allowed to assess the saturation state for CO_2 and O_2, de-convolute the observed disequilibrium into its physical and biological drivers and calculate air-sea CO_2 and O_2 fluxes.

Module 2, *Marine ecology*: The cruise track covered different biomes and offered the opportunity to characterize the associated pelagic ecosystems as well as local communities (e.g., seamount, eddies). To facilitate integration of results, the main aim was to use methods that readily can be used to estimate zooplankton contribution to biomass, bulk metabolic rates and export flux. Specifically, the total integrated zooplankton biomass at each station and the contribution of larger taxonomic groups at selected sites have been determined.

Module 3, *Time-series observations*: Full-depth CTD hydrocasts including biogeochemical sampling at different time series sites (CVOO and ESTOC) have extended long-term data sets of these sites. Conducted samplings will facilitate the assessment of long-term biogeochemical (e.g., deoxygenation and acidification) and ecological (e.g. zooplankton) changes in the ETNA.

Module 4, *Microplastics:* a) Comparing the abundance of microplastics inside and outside mesoscale eddies of which presence along the cruise track will be assessed prior and during the cruise, b) collecting microplastic surface samples at stations along the cruise track, c) testing a newly developed hyperspectral camera system for onboard analysis of plastic particles.

3.3 Agenda of the Cruise

MSM106 combined a curricular education cruise with a scientific expedition in a highly synergistic manner. West African students were involved in the scientific work program. The cruise was based on 3 pillars:

- Educational component
- Underway work
- Station work

Educational component

The educational component consisted of 3 lecture modules (see above) that were addressed during MSM106. Beside daily seminars students were grouped and got involved in daily sampling and measurement routines. Student groups rotated between different observational components and working groups.

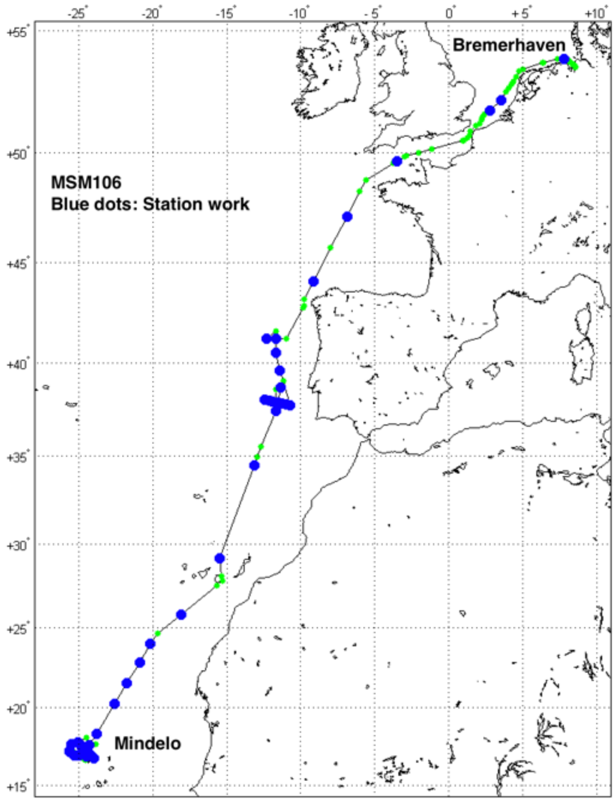

Fig. 3.1 Track chart of R/V MARIA S. MERIAN MSM106 cruise. Blue dots denote station work during the transit from Cabo Verde to Germany.

Underway work

Underway work included continuous hydroacoustic measurements for ocean currents and backscatter as well as biomass, an underway seawater flow-through system that includes a variety of biogeochemical sensors for continuous surface seawater measurements during the ship's transit.

Station work

Station work was supposed to be carried out along the transit with daily stations on roughly equidistant spacing and in the following 5 working areas along the transit:

1) Cape Verde Ocean Observatory (CVOO, long-term time series station)
2) Senghor Seamount (open-ocean seamount, summit water depth: 105 m)
3) Cape Blanc Observatory (long-term time series station)
4) European Station for Time Series in the Ocean Canary Islands (ESTOC, long-term time-series station)
5) Eddy survey (dynamic mesoscale oceanographic feature)

Working areas 2) and 3) had to be cancelled due to time constraints resulting from an onboard COVID-19 infection that caused changes in the work program (refer to next section).

Working areas 1) and 4) were fixed-point and long-term time-series stations at which a deep CTD/UVP hydrocast including biogeochemical sampling, a multinet day and night haul as well as a neuston net haul were conducted.

Working area 5) were dynamic eddy features northeast of Cabo Verde and off Portugal. Eddies within these target areas were identified by satellite sea level anomaly data and ground-truthed by dedicated ADCP and CTD surveys which consisted of CTD/UVP hydrocasts, multinet and neuston catamaran trawls in order to resolve eddy characteristics.

4 Narrative of the Cruise

Expedition MSM106 started on Feb 26th in the morning from the port of Mindelo, Sao Vicente, Cabo Verde. The first working area was located 12 nautical miles west of the island of Santo Antao at Nola Seamount. Approx. half way on the approach to the seamount a short stop south of the island has been carried out in order to calibrate the SIMRAD WBT Mini echosounder (38/200kHz) which got installed in the vessel's moonpool.

At the seamount an oceanographic mooring with a newly developed surface buoy was deployed at the southwestern flank of the seamount at a water depth of 200 m. The buoy was equipped with a new measurement system for CO_2 to measure both in atmosphere and in water.

Shortly after mooring operations were finished, an autonomous surface vehicle (Wave Glider) equipped with a similar CO_2 system got deployed in the vicinity of the mooring. The Wave Glider then got tasked to circumnavigate the mooring in a safe distance for several days in order to conduct simultaneous CO_2 measurements to compare data from both units with each other and to determine submesoscale variability at the seamount.

Right after deployment of the Wave Glider the initially planned scientific work program had to be paused because of a detected COVID-19 case on board. All scientific operations had to stop immediately on board and infection prevention measures were strengthened according to the expedition's outbreak management plan. Hence, the work program got immediately adapted to the new circumstances. Only hydroacoustic profile sections with the vessel-mounted 75 kHz Acoustic Doppler Current Profiler (ADCP) and the SIMRAD WBT Mini echosounder could be carried out. Hydroacoustic profiles with the two above mentioned instruments were conducted across the two summits of Nola Seamount during the evening of Feb. 26th, followed by a zonal section across a mesoscale eddy during the night of Feb. 27th, which has been detected via remote sensing before.

Later during the day, the near-coastal area north of the islands of Sao Vicente and Santa Luzia were approached for a high-resolution hydroacoustic grid survey in order to investigate the boundary currents as well as the distribution of biomass in the water column from the coast to the open ocean. Measurements revealed a pronounced shear between near-coastal boundary currents and currents induced by the mesoscale eddy further north of the islands.

After the coastal survey a meridional section through the before-surveyed eddy candidate was performed on Feb 28th to determine the geometry and thus the centre of the eddy.

On March 1st station work - with scientific gear that could be operated single-handed – became possible again. A hydrographic section (down to 1200 m) with 9 CTD hydrocasts (incl. water sampling) across the eddy and through its centre was performed. Further, the sampling of organic surfactants at the sea surface has started with a so-called Garrett-Screen sampler which gets lowered to the sea surface by hand at every station during MSM106. Furthermore, the towed camera system PELAGIOS has been deployed during the section at eddy-outside and eddy-centre stations (2.5 hrs per tow, down to 1200 m).

On March 2nd all gears could finally be operated when the COVID-19 outbreak turned out to be under control. The multinet (down to 1000 m) for zooplankton sampling, the IKMT for nekton sampling (down to 800 m) and the catamaran for microplastic sampling at the sea surface were deployed for the first time at the eddy centre station. This station got revisited for a second time after the section got accomplished. At the end of station work in the eddy centre (the eddy was found to be an anticyclonic mode-water eddy with a low-oxygen core) a biogeochemical Argo float got deployed.

In the evening of March 2nd MARIA S. MERIAN arrived at the Cape Verde Ocean Observatory (CVOO) to carry out a full time series sampling which included a full-depth CTD hydrocast (3600 m) incl. water sampling, Zooplankton and microplastic samplings.

Due to the significant changes in the scientific work program caused by the COVID-19 case on board, the working areas at Senghor Seamount and at the Cape Blanc time series site had to be canceled and the transit to Las Palmas started on March 3rd early during the night. Along the transit, daily stations with different gears have been performed to facilitate the student training program on board. Further, 4 Argo floats as a contribution to the international Argo program were deployed along the transit.

On March 7th a short port call of 9 hrs was carried out to exchange a few scientific crew members. After 4 new scientists have embarked, MARIA S. MERIAN proceeded in the late afternoon with its transit towards Bremerhaven in Germany. Already at midnight the Spanish time series site ESTOC 60 nautical miles north of Gran Canaria was reached. A full time-series sampling equivalent to the CVOO sampling has been carried out until the next morning.

Along the transit, the daily station work has continued until March 10th when a second mesoscale eddy candidate off the COAST of Portugal got reached. A first meridional ADCP section was conducted to determine the eddy geometry and its centre. Consecutively, a hydrographic section with 7 stations across the eddy was conducted, equivalent to the survey off Cabo Verde.

During the eddy survey a 45-minute livestream event (performed by the students) as part of an UN Decade of Ocean Sciences for Sustainable Development event was broadcasted to explain and illustrate marine research to a wide international public.

After the eddy survey was accomplished, another daily station was performed on March 12th and on March 13th a third eddy candidate was surveyed by two orthogonal ADCP sections and one centre station including CTD, multinet and catamaran.

The daily station works then continued until March 16th in the English Channel with its last daily station carried out off the British Channel Islands. The final station work was then conducted with two microplastic samplings off the Rhine River delta on March 17th.

Due to beneficial currents in the English Channel MARIA S. MERIAN reached the port of Bremerhaven already during late evening of March 18th.

5 Preliminary Results

5.1 Physical Oceanography

5.1.1 CTD Measurements

(T. Fischer, N. Vieira, D. Tora, S. Idrissa, A. Pinck)

Introduction

During the MSM106, a total of 29 vertical profiles of pressure (P), temperature (T), conductivity (C) and oxygen (O) were recorded. Most CTD/O_2 profiles ranged from the surface to 1200 m depth, and only three full depth profiles were taken (CVOO, ESTOC and off France).

Methods

We used a Seabird Electronics (SBE) 9 plus system attached to the water sampler carousel and recent SBE Seasave software (Fig. 5.1). The SBE underwater unit had, in addition to its own pressure sensor, two parallel sensor sets for T, C, and O. Many additional sensors were attached to the CTD frame: A Wetlabs fluorescence sensor (SN 2484), a Wetlabs CDOM sensor (SN 3705), and a photosynthetically active radiation sensor (PAR). Furthermore, an underwater vision profiler (UVP) was mounted on the CTD frame. An altimeter system (SN 1111) was used during the cruise for bottom distance detection of the CTD. The CTD system itself performed without significant problems throughout the whole cruise.

The serial numbers of the primary sensors (1) and secondary sensors (2) were 4219 (T1), 6367 (T2), 1390 (C1), 2942 (C2), 78962 (P), 3826 (O1) and 0157 (O2). A malfunctioning was observed on 3/14/2022 with some bottles of the CTD which were not closed at their different depths. But later, the issue was revealed to be the effect of the bad weather of that day. Indeed, because of the high waves, the descent rate of the rosette was too slow, which caused the cable to lay on the rosette preventing a certain number of bottles from closing.

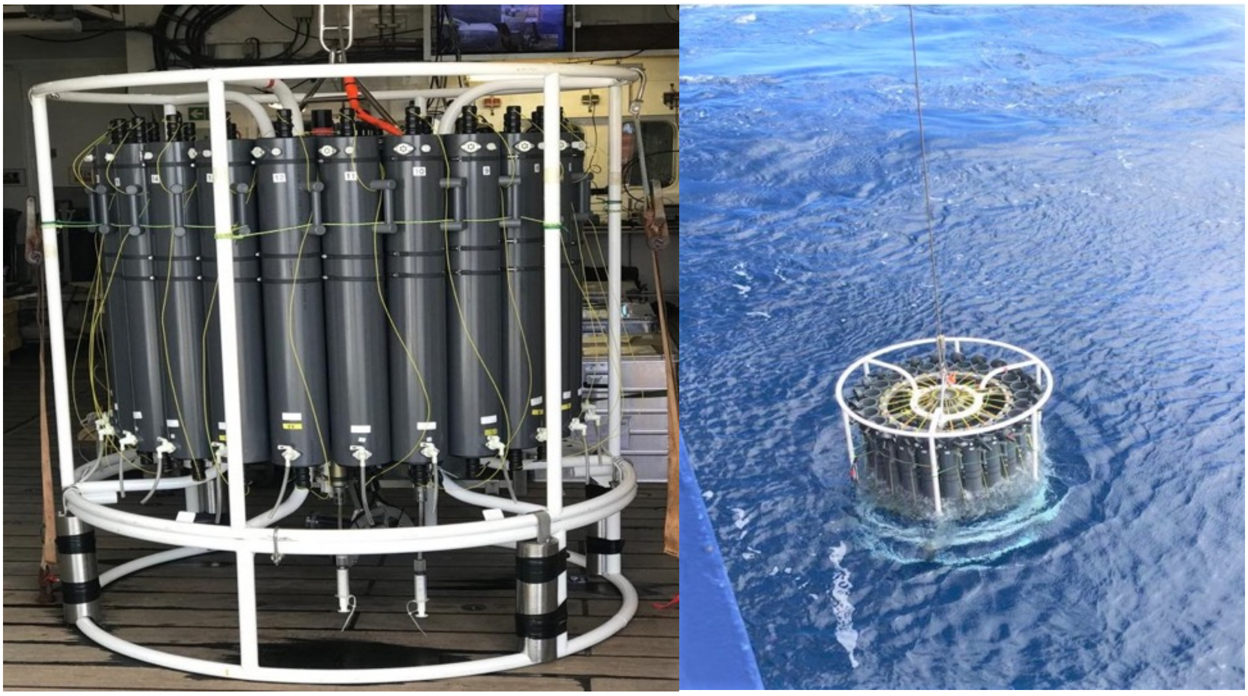

Fig. 5.1 CTD Rosette system (from IOW, Warnemünde, Germany) used during MSM106 on deck (left) and during deployment (right).

For calibration of the conductivity cell, 130 salinity samples were taken, and the measurement of 80 of them will be done in Germany. 50 of the samples were measured onboard using an RBR Micro-Salinometer MS-315. The standardisation of the salinometer was performed using IAPSO standard seawater. The salinometer has an accuracy of +- 0.002 PSU and a resolution <0.001 PSU. Despite the RBR's small dimensions, the concept of difference measurement in an oil bath leads to its competitive accuracy.

For the calibration of the oxygen sensors 250 measurements of the dissolved oxygen content from water samples using Winkler titration were used.

Preliminary results and outlook

A CTD section across the anticyclonic mode water eddy (Fig.5.2) shows the typical lense shape in density, and distinctly reduced oxygen concentration within the trapping radius.

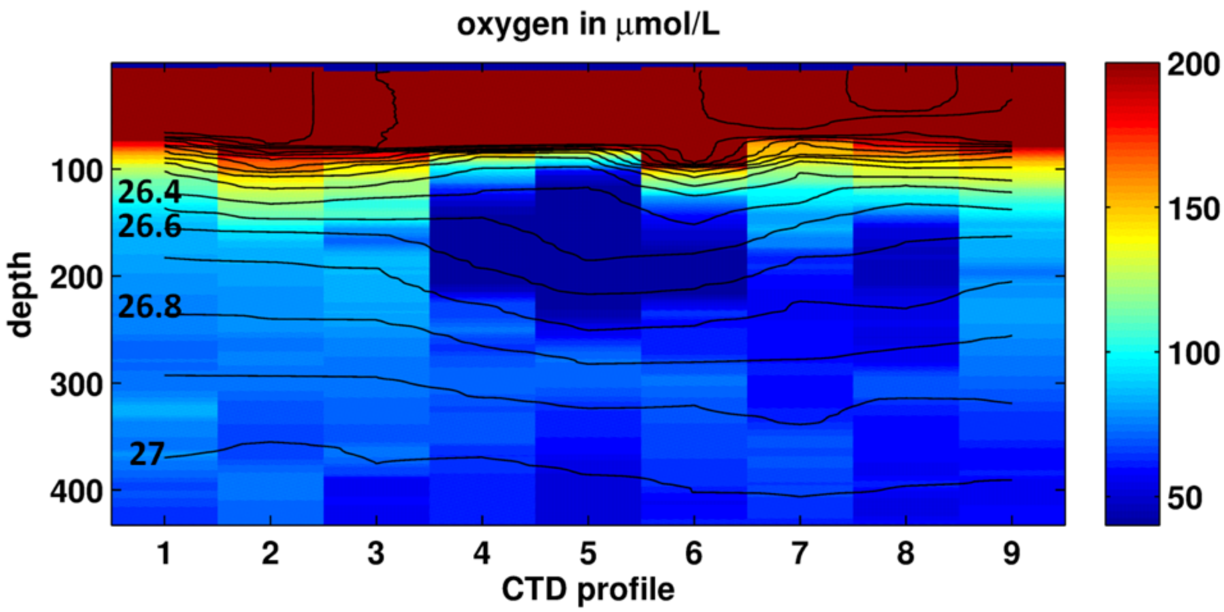

Fig 5.2 Oxygen concentration (color) and density (black contours) from the CTD section across the anticyclonic mode water eddy off Cape Verde. CTD profile numbers correspond to Fig.5.3.

5.1.2 Underway Hydroacoustic Current and Hydrographic Measurements

(T. Fischer, N. Vieira, D. Tora, S. Idrissa, A. Pinck)

Introduction

During MSM106 continuous measurements with the vessel-mounted Acoustic Doppler Current Profiler (VM-ADCP) and the thermosalinograph were carried out in order to facilitate the localization and identification of mesoscale eddy candidates. In order to carry out a dedicated sampling program across these eddies a detailed knowledge about their geometries is required.

Methods

Only the hull-mounted 75kHz ADCP system could be used, as the moon pool was occupied by the underway water sampling system. The 75 kHz RDI Ocean Surveyor worked throughout the entire cruise from Feb 26, 10:15 UTC to Mar 17, 16:23 UTC without fail. It was configured to broadband mode with 8 m-bins for the largest part of the cruise, reaching depth ranges of 500 m. In shallow waters, broadband mode with 4 m-bins was used, from Feb 26, 12:00 UTC to Feb 27, 00:06 UTC above Nola Seamount, and from Feb 27, 18:16 UTC to Feb 28, 11:45 UTC when scanning the northern coasts of Sao Vicente and Sao Nicolau.

After Mar 10, 13:09 UTC, the configuration was changed to the more robust narrowband mode with 8m-bins due to worse sea conditions. Since Mar 15, 12:53 UTC, when the European shelf was reached, bottom tracking was added. The transducer misalignment was always preset to 48 degrees (EA48 in the VmDAS software options), so that the misalignment bias of the preprocessed velocities was better than 1 cm/s, i.e. even during cruising at 12 knots the current velocity and direction could be immediately read from the screen.

The SBE21 thermosalinographs (TSG) permanently installed on RV MARIA S. MERIAN continuously sampled sea surface temperature (SST) and salinity (SSS). Both were constantly running during the whole cruise. The seawater intakes at the vessel's hull are located at 5 m depth on the port side and starboard side bow. Two external sensors measure temperature at the intakes, while the TSG are situated further inside the vessel.

Preliminary results and outlook

The ADCP derived currents show that the two surveyed eddies were strong and pronounced (left panel of Figure 5.3 for the anticyclonic mode water eddy off Cape Verde, right panel for the anticyclone off Portugal). The data quantity and quality allowed to estimate three kinds of limit radii: (1) inner radius with about linear velocity profile (i.e. solid body rotation); (2) medium radius with zero vorticity (which is approximately the trapping radius); (3) outer radius with about zero velocity (limiting the 'shield').

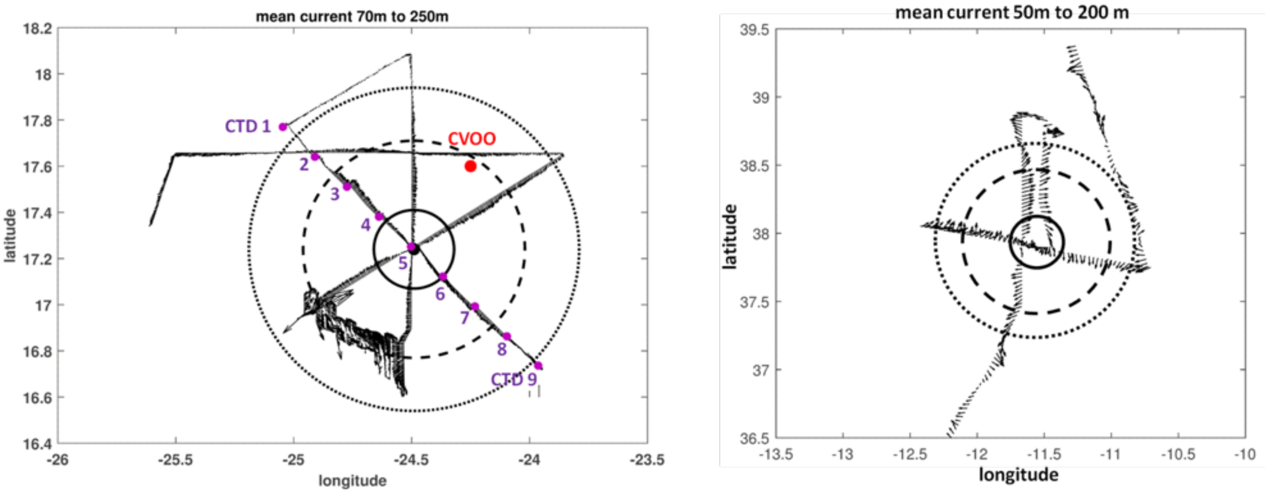

Fig 5.3 The anticyclonic mode water eddy off Cape Verde (left) and the anticyclonic eddy off Portugal (right). Violet points: CTD profiles across the eddy. CVOO: timeseries station and mooring. Solid black circle: radius of solid body rotation. Dashed black circle: trapping radius. Dotted black circle: eddy shield limit.

5.1.3 Argo Float Deployments

(B. Fiedler, T. Fischer, A. Pinck)

A total of 4 standard Argo floats (Table 5.1) were deployed during MSM106 on behalf of the Bundesamt für Seeschifffahrt und Hydrographie in Hamburg (BSH). Float deployments are a national contribution to the international Argo program.

In addition, one biogeochemical Argo Float equipped with an Aanderaa oxygen optode 4330, a Wetlabs ECO_FLBBCD fluorometer and a Seabird SEAFET pH probe was deployed near CVOO (WMO no. 7901001).

Table 5.1: Time and location of Argo float deployments during MSM106.

WMO Number	Date and Time UTC	Latitude	Longitude
7901001	2022-03-02 17:09	17° 15,143' N	024° 30,183' W
6904124	2022-03-04 11:14	20° 22,744' N	022° 29,484' W
6904123	2022-03-04 20:01	21° 33,328' N	021° 43,765' W
6904122	2022-03-05 08:37	22° 55,650' N	020° 47,441' W
6904125	2022-03-05 17:24	24° 13,220' N	019° 58,704' W

5.2 Biogeochemistry

5.2.1 Water Sampling & Underway Measurements

(T. Steinhoff, B. Fiedler, N. Vieira, M. Ndure, G. Soro)

Introduction

A diverse suite of discrete water samples was collected during the cruise from both vertical CTD/RO hydrocasts and the seawater underway system. Biogeochemical and biological parameters were used to investigate spatial distributions in- and outside mesoscale eddies to better understand biogeochemical cycling of carbon, nitrogen and oxygen across eddy boundaries. Biogeochemical samples will be also used to calibrate CTD and underway biogeochemical sensors.

Discrete water samples were collected from 29 CTD casts for nutrients (nitrate, nitrite, phosphate and silicate; 225 samples), dissolved oxygen (DO; 251 samples), dissolved inorganic carbon (DIC; 40 samples) and biogeochemical surfactants (29 samples). Dissolved oxygen analysis was done onboard while samples for nutrients were preserved in freezers (-20°C), DIC samples were preserved with a saturated $HgCl_2$ solution. Nutrient, DIC and biogeochemical surfactant samples were transported to the GEOMAR lab in Kiel for analysis.

Water was also collected for chlorophyll-a (144 samples) to ascertain concentration measurement as an indicator for biological productivity.

Methods

Oxygen samples

The sampling was done in 100 mL glass bottles with glass stoppers. Each bottle was rinsed at least three times before filling to the top. Following this, 1 mL $MnCl_2$ and 1 mL KI solution were added to each bottle. The bottles were closed and then shaken for approximately one minute, stored in a dark cupboard for at least 2 hours and max. 12 hours before analysis. Oxygen samples were analysed according to the standard Winkler titration (REF). One duplicate or triplicate sample was collected for each CTD cast to measure sampling and titration precision. Reagents for Winkler titration were checked regularly against a certified reference solution of potassium iodate (OSIL, Havant, UK).

Nutrient samples
The nutrient water samples were collected in PE vials. Each vial was rinsed three times, filled with three-quarters of water from the Niskin bottles and immediately stored in a -20˚C freezer. These samples will be measured at GEOMAR with a Seal Quattro (Seal Analytical, Norderstedt, Germany) autoanalyzer.

DIC/TA
Samples for dissolved inorganic carbon (DIC) and total alkalinity samples were collected in 250 mL glass bottles with glass stoppers from the CTD/RO. The preservation procedure followed the recommendations from Dickson, Sabine, & Christian, 2007. The samples were preserved with mercury chloride based on the recommendations from (Dickson et al. 2007) and stored in the dark. Onshore DIC samples will be analyzed with a coulometric titration method using the SOMMA (Single-Operator Multiparameter Metabolic Analyzer). TA will be determined by a semi-automatic analyzer, the VINDTA (Versatile Instrument for the Determination of Titration Alkalinity).

Biogeochemical surfactants
Samples of the Sea Surface Microlayer (SML) were collected using a Garrett Screen for the analysis of Dissolved Organic Matter (DOM) (< 0.7 µm) and Surfactant Activity to investigate spatial variation of SML composition in the North Atlantic. The Garrett Screen works by lowering a 50 cm2 wire mesh to the surface of the ocean where it "kisses" the surface, trapping the SML between the mesh pores. The Garrett Screen is then lifted up and tilted, allowing the SML to drain into a sample container, which is then immediately frozen at -20 °C. Subsurface Waters (SSW) were also collected via a Niskin bottle on the CTD rosette (at 2-10 m depths). Once the samples are at Heriot-Watt University, they will be defrosted and each sample (both SML and SSW) will be split into aliquots for Surfactant Activity analysis using polarography, and DOM analysis using a size exclusion Liquid Chromatography approach with Organic Carbon Detection Organic Nitrogen Detection (LC-OCD-OND). A total of 59 samples were collected from the cruise (29 x SML, 30 x SSW) in 120 ml sample containers by 2 students: Daniel Tetteh Quaye and Djibril Konate. This work will provide valuable input to a PhD study, which is investigating changing sources of organic compounds on the SML composition and its control on air-sea gas exchange.

Chlorophyll a
Samples for measurements of Chlorophyll-a concentration were taken from 22 casts, from 5 to 7 Niskin bottles from a depth between 5 – 200 m. The plastics bottles (2 L) were rinsed three times before collecting the final sample. The water was filtered through 25 mm GF/F filters as soon as possible. The filter paper was then transferred to a plastic screw cap tube, 5 ml of acetone was added, and the tubes were stored in a freezer (-20˚C) for 24 hrs. The following day, the samples were analysed using a Turner Trilogy Laboratory Fluorometer (serial number 015526).

Underway sensor package

A flow through box connected to the vessel's continuous seawater supply system (rotary pump) was installed in the Hangar with an approx. seawater flow of 10 L min^{-1}. Submersible sensors for measuring the partial pressure of CO_2 (pCO_2, CONTROS HydroC, sn: 1011-006), dissolved oxygen (Seabird SBE63, sn: 630023), conductivity (4319A, Aanderaa Instruments AS, Bergen, Norway, SN 4319-772), fluorescence & turbidity (FLNTURT, Sea Bird Electronics, Bellevue, USA, SN 4899) and total gas tension (HGTD, Pro-Oceanus Systems Inc., Halifax, Canada, SN 28-086-42) were deployed in this box. Data from all sensors were recorded centrally on a 60 s time interval (see Fig. 5.5).

Biogeochemical surface buoy

A short-term mooring with a surface buoy attached to it was deployed at Nola Seamount west of the island of Santo Antao at 200 m water depth. The buoy was equipped with a VeGas pCO_2 measurement system (HTECH, South Africa, SN M2001002) for air and water measurements, a Gill GMX501 weather station (SN 1957-0501-60-000), Iridium and AIS beacons and a SBE37-SMP-ODO Microcat (Sea Bird Electronics, Bellevue, USA, SN 9510). Data for pCO_2 were measured every 15 minutes while other data were measured in a 1-minute interval. The targeted deployment duration was 3 months. A detailed drawing of the mooring can be found in section 11.2.

Autonomous surface vehicle

Continuous measurements of biogeochemical parameters in the ocean's surface were carried out using a Liquid Robotics, Inc. SV3 Wave Glider (Sunnyvale, USA, SN SV3-193). The Wave Gliders was equipped with a BGC sensor package consisting of a VeGas pCO_2 measurement system (HTECH, South Africa, SN G2001001), an oxygen sensor (SBE63, Sea Bird Electronics, Bellevue, USA, SN 63-0392), a two channel fluorometer (FLNTURT, Sea Bird Electronics, Bellevue, USA, SN 2493) measuring turbidity and fluorescence and a sensor to measure the total gas pressure of all dissolved gases (Mini TDGP, Pro-Oceanus Systems Inc., Halifax, Canada, SN 38-511-31).

Preliminary results and outlook

The precision of the oxygen analysis varied throughout the cruise (Fig. 5.4). This could be because several students were involved in sample collection and analysis. Some of the 251 DO samples may have been over-titrated or collected from the wrong Niskin bottles, and for some, air bubbles were introduced during the sampling. Therefore, outliers may have occurred during sample collection or data analysis. However, overall replicate measurements for the oxygen samples during MSM106 showed good precision (0.32 µmol L^{-1}).

Samples for nutrients and DIC/TA were preserved on board for later onshore analysis at GEOMAR in Kiel.

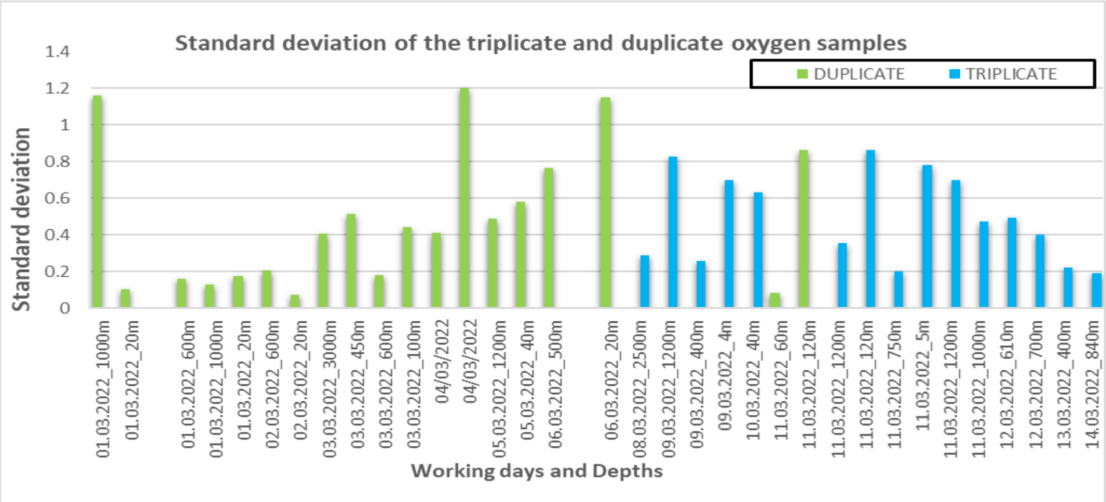

Fig 5.4 Standard deviation of triplicate and duplicate oxygen samples in µmol L^{-1}.

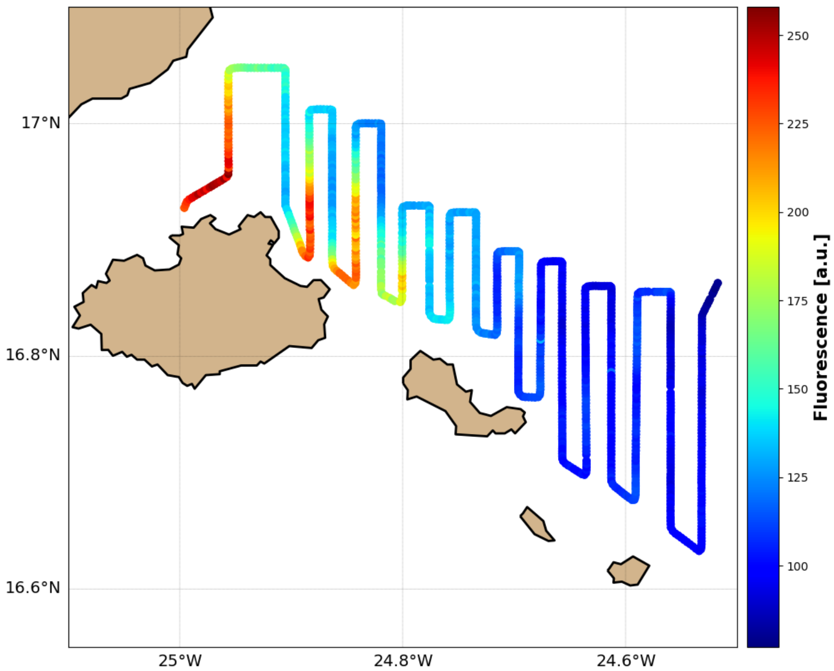

Fig. 5.5 Underway fluorescence measurements as a proxy for Chlorophyll-a distribution upwind of the islands Sao Vicente and Santa Luzia in Cabo Verde.

5.3 Marine Ecology

5.3.1 Mesozooplankton, Macrozooplankton and Micronekton Sampling

(H. Fock, H. Andresen, H. Hauss, M. Schaber, T. Oyikeke, D. Konate)

Introduction

During leg I and II of MSM106, a Multi Plankton Sampler (MultiNet "Maxi", MN) was deployed at five and seven stations, respectively, for the stratified collection of zooplankton samples in different water layers. For the collection of macrozooplankton and micronekton, an Isaacs-Kidd Midwater Trawl (IKMT) was used at three stations (Fig 5.6). The sampling strategy was designed primarily for educational purposes, e.g. to reveal differences in depth distributions between day and night in terms of biomass and individual densities. Small mesopelagic fishes from both nets were identified to investigate geographic changes in faunal composition.

Methods

The IKMT net was towed behind the ship at a speed of 2.5 knot and lowered to a maximum depth of 160 m, 300 m or 1260 m (at Stations 24, 28 and 42, respectively) at a winch speed of 0.7 m/s (or 1 m/s at Station 42), after which it was towed back to the surface with a winch speed of 0.5 m/s. The Multinet is equipped with nine nets attached to a steel frame. It was lowered to 480 m at the two ESTOC stations, to 50 m at station 43 on the shelf, and to 780 at the remaining stations. The opening and closing of the separate nets was switched via a deck command unit, with smaller depth increments towards shallower depths. Samples were preserved with 4% Borax-buffered formaline and will be scanned at GEOMAR for quantitative analysis using the ZooScan method.
At the ESTOC stations (24 and 25), zooplankton biomass depth distributions were compared between day and night hauls with a volumetric method (settled volume).

Fig. 5.6 IKMT (Isaacs-Kidd Midwater Trawl net, left), MN (Multinet, right).

Numerical densities of copepods were obtained using subsampling for stations 37 and 40. Copepods are a main prey of marine fish larvae, because they have a high nutritional value, stimulate feed response, and have a wide size range.

To determine the copepod concentration at a particular water depth, students used the following equation:

Concentration of copepods in water layer: A (n/m^3)

$$\mathbf{A = \boldsymbol{n} * X/\boldsymbol{x} * 1/V}$$

Volume of the subsample: x (ml)
Filtered volume through the net: V (m^3)
Container size: X (ml)
Number of copepods in subsample: n

Mesopelagic fish species were identified using identification keys, with the aid of stereomicroscopes. The number and position of photophores (light organs) is an important discerning feature. Sampling positions were compared with reported species distributions.

Preliminary results and outlook

Zooplankton biomass shifted to shallower depths at night, an illustration of the biological carbon pump. The density of copepods obtained from two stations was highest at the shallowest depth between 6-40 m. However, station 40 at the center of an Eddy had more copepods overall and most notably shows another density peak between 80 to 120 m, in contrast to station 37 (Fig. 5.7).

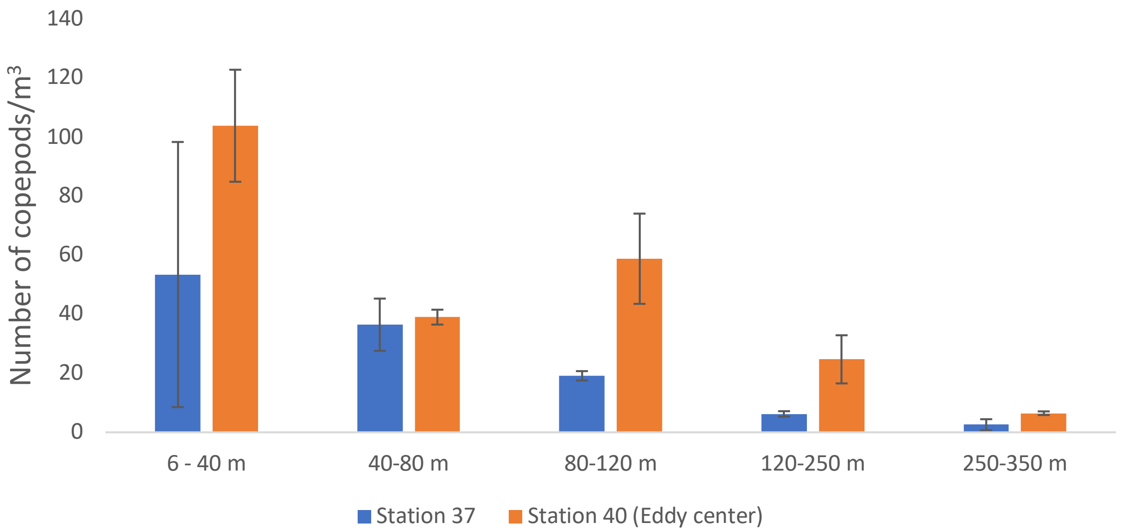

Fig. 5.7 Density of copepods by sampling depth.

Mesopelagic fish species (Fig. 5.8) identified across different stations were mainly of the orders Myctophiformes and Stomiiformes. *Argyropelecus hemigymnus* had the largest geographic range and was present at almost all analyzed stations (except station 24; table 5.2). Apart from this rather cosmopolitan species, a change in faunal composition from mainly subtropical to more boreal species was observed along the cruise route.

Table 5.2 Table of species identified during MSM 106

Order	Species	Station 16 (Eddy)	Station 24	Station 25	Station 28	Station 42
Myctophiformes	*Ceratoscopelus maderensis*		X			
	Bolinichtys indicus		X			
	Benthosema suborbitale		X			
	Lampanyctus alatus		X			
	Benthosema glaciale					X
	Lampanyctus pusillus		X			
	Myctophum nitidulum		X			
	Myctophum punctatum				X	
	Ceratoscopelus warmingii				X	
	Lampanytus ater				X	
Stomiiformes	*Vinciguerria nimbaria*		X			
	Gonostoma atlanticum		X			
	Argyropelecus hemigymnus	X		X	X	X
	Argyropelecus cf. *aculeatus*	X				
	Valenciennellus tripunctulatus			X		
	Argyropelecus olfersi				X	X
	Chauliodus danae	X				
	Borostomias antarcticus					X
Others	*Scomberesox saurus*			X	X	
	Winteria telescopa	X				
	Avocettina infans				X	

Fig. 5.8 Mesopelagic fish species collected during MSM106.

. 5.3.2 Pelagic Video Surveys

(H. Hauss, H.J. Hoving, M. Schaber)

The pelagic in situ observation system or PELAGIOS is an ocean observation instrument that is slowly towed at 0.5-1 kn over the side of the ship on the on the conducting cable (Hoving et al 2019). The PELAGIOS was deployed six times during the first leg, three times in standard operation mode and three times with a Simrad WBAT autonomous echosounder mounted underneath, with transducers (38 and 120 kHz) facing forward (Fig. 5.9). Unfortunately, annotation of the transects is quite difficult because of the wave height during all six deployments, and is now focused on the large pneumatophore-bearing siphonophores and larger crustaceans.

We did encounter several individuals of the flux-feeding polychaete *Poeobius sp*. In eddy 1, which has been observed in several other productive eddies in the region too (Christiansen et al. 2018).

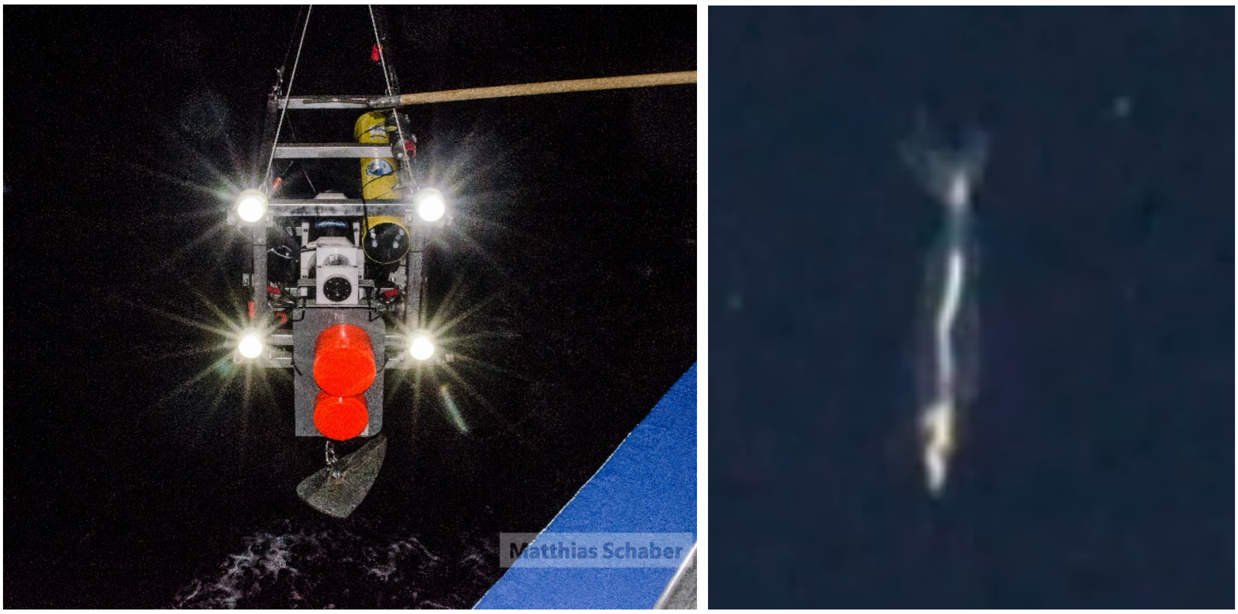

Fig. 5.9 Left: PELAGIOS underwater camera system with Simrad WBAT autonomous echosounder (yellow pressure housing, red transducers) mounted, right: *Poeobius* in eddy1.

. 5.3.3 Underwater Vision Profiler 5 (UVP5)

(H. Hauss)

To study the composition, distribution and dynamics of plankton and marine snow, the Underwater Vision Profiler UVP5 (Picheral et al. 2010) was mounted on the CTD/RO. The UVP5 acquires greyscale images and directly processes the abundance of particles starting at a pixel size of approximately 60 µm. The UVP5 data (particle abundance in different size bins as well as image data) will be matched to calibrated CTD/RO profiles and are stored and sorted into taxonomic categories using Ecotaxa (https://ecotaxa.obs-vlfr.fr/).

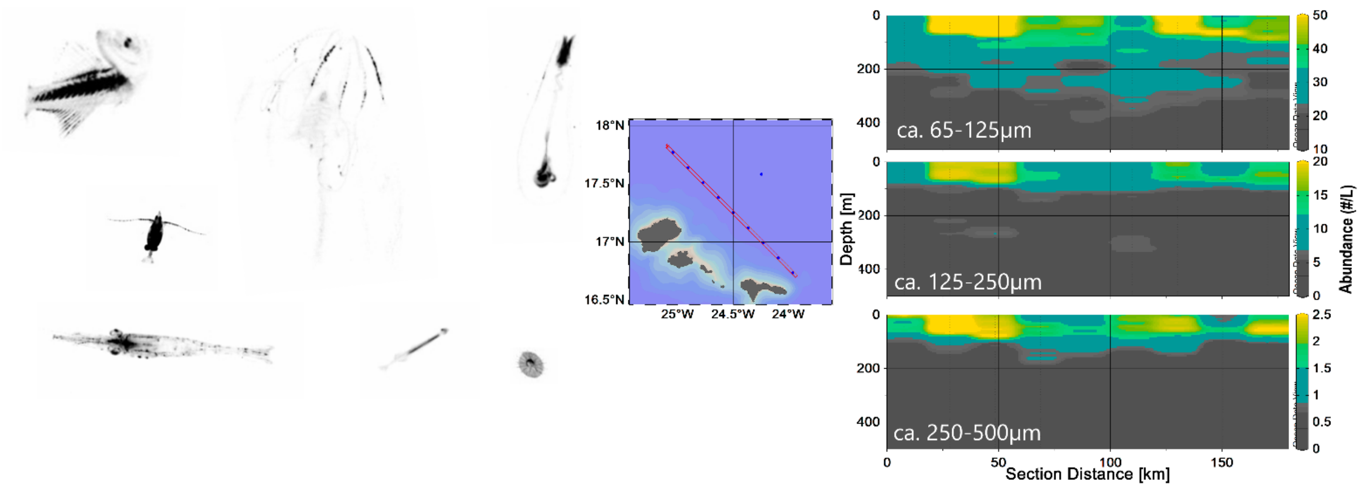

Fig. 5.10 Left: Examples of UVP5 images (fish, ctenophore, Poeobius, copepod, euphausiid, chaetognath, phaeodarian), right: particle abundance section (three size classes) through eddy1.

After taxonomic classification and in-depth analysis of the data, small-scale distribution of different types of particles and species will be available. The particle distribution data are available on https://ecopart.obs-vlfr.fr/. In eddy1, particle export flux appeared to be higher at the margins than in the center (Fig. 5.10).

5.3.4 Underway Hydroacoustic Observations

(M. Schaber, H. Hauss, N. Vieira, H. Fock, H. Andresen)

Introduction

The use of active acoustic techniques by means of scientific echosounders allows for a variety of approaches to study pelagic marine ecosystems and life in the ocean. Scientific echosounders allow rapid sampling at a high temporal and spatial resolution, are non-invasive, and often allow synoptic observations of ecosystems and processes (Benoit-Bird & Lawson, 2016). Apart from their use in characterizing (meso)pelagic ecosystems in open ocean habitats as well as their structure and inhabitants, hydroacoustic methods are also a standard tool to provide estimates of abundance, biomass and population dynamics of fisheries resources, especially small pelagic fishes.

Methods

To study both the structure of mesopelagic habitats in the open ocean areas of the survey region, inside/and outside of the eddies as well as in the vicinity or above the top of the seamounts samples and the distribution of small pelagic fishes throughout the survey area, a hull mounted scientific echosounder was employed. Since RV MARIA S. MERIAN is not equipped with a scientific ("fisheries") echosounder, a mobile Simrad WBT Mini echosounder was installed in the CTD-laboratory and operated with a 38/200 kHz combi-transducer that was flush-mounted in the moon pool of the vessel. Prior to the start of survey operations, the echosounder/transducers were calibrated in a sheltered region south of Santo Antao with the standard sphere method (Demer et al., 2015). All transducers were calibrated in CW-mode with good/acceptable results based on calculated RMS-values. Transducer parameters from combined calibration results were applied for data-collection and post-processing of survey data. Hydroacoustic data were collected continuiously during survey operations, i.e. along transects and during transit at a vessel speed of ca. 10-12 knots, as well as during station work. Power output was set to maxiumum in both frequencies, pulse length was set to 1.024 ms at the highest possible (fixed) ping rate.

Preliminary results and outlook

During the recording of hydroacoustic data while the vessel was either steaming or positioning it became evident that both the comparatively low output power of the WBT Mini as well as the significant noise from the vessel/propellers etc. reduced both the vertical depth range of hydroacoustic data deemed of sufficient quality for post-processing as well as the data quality itself. Background and other noise in many cases (e.g. bad weather or heading into the sea/waves, operating of the positioning system) led to reduced data quality.

Using different modules and algorithms to reduce noise etc. (Ryan et al. 2015) during post-processing the data with Echoview software (Echoview Software Pty Ltd, 2021), the data recorded at 38 kHz from the surface to ca. 600 m depth was considered useable.

While currently not yet further analysed and e.g. combined with biological data collected with the IKMT and MultiNet, the data still showed the presence of typical sound scattering layers in different depths. These layers are typical features of open ocean (meso)pelagic ecosystems and are comprised of a variety of invertebrate and vertebrate organisms. A noteable, persistent deep scattering layer was recorded and observed in depths of ca. 400 m. Additionally, the epipelagic surface layer (and especially the upper ca. 50 m) showed distinctly increased densities of backscattering organisms. Diel vertical migration of mesopelagic organisms from the deep layers to surface layers at nightfall as well as back into deep layers at dawn was observed throughout the survey operations with corresponding migrants becoming visible as ascending and descending layers (Fig. 5.11).

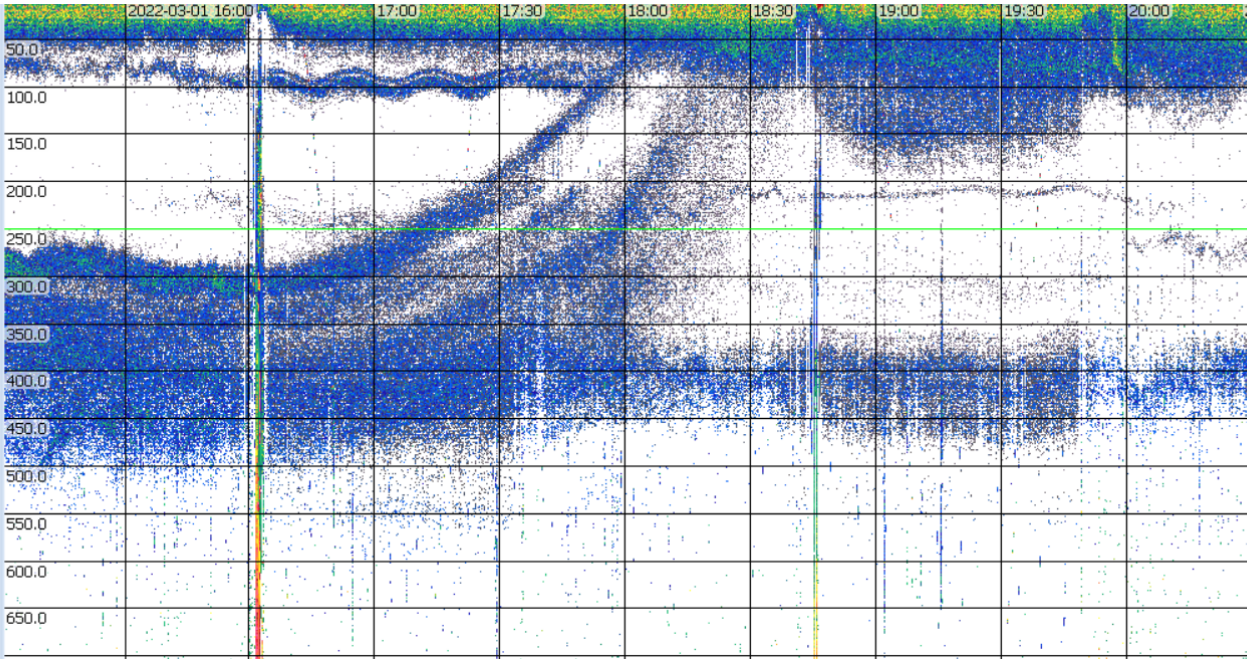

Fig. 5.11 Exemplary echogram showing the ascending period of the diel vertical migration of mesopelagic organisms emerging from the deep scattering layer at ca. 400m and ascending to surface layers at dusk. Spikes/vertical signals are from vessel noise.

Additionally, spatial differences in total backscatter measured became evident from e.g. the high-resolution hydroacoustic transect grid north of Sao Vicente and Santa Luzia (Fig. 5.12).

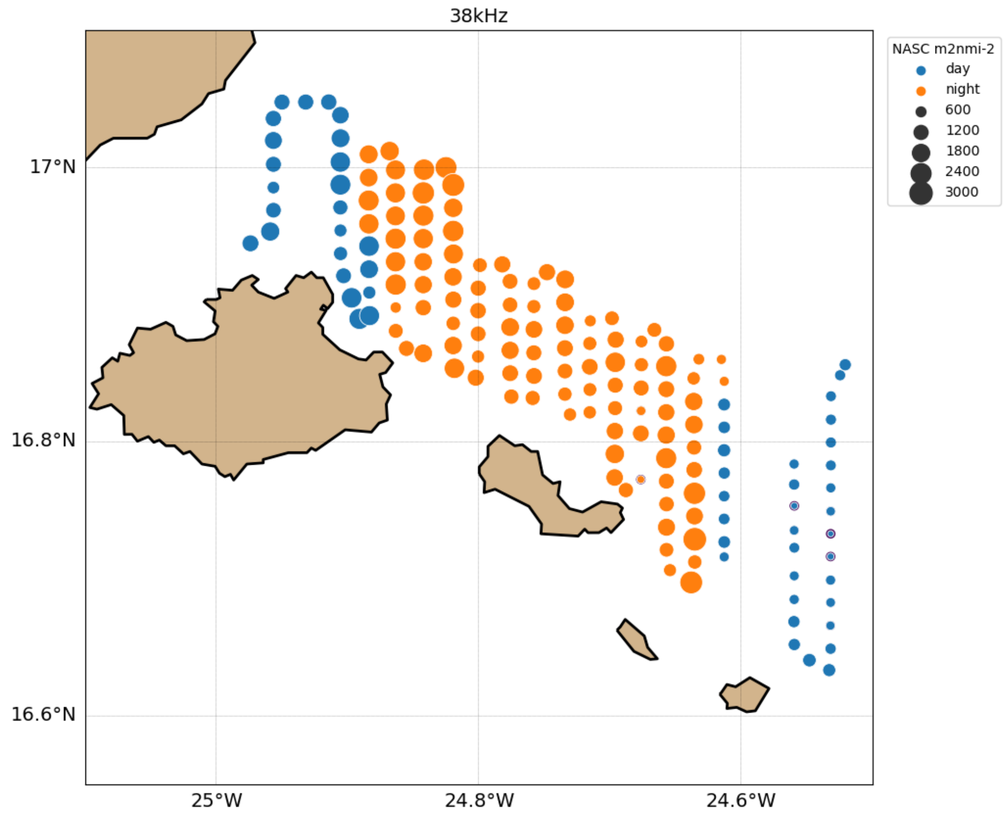

Fig. 5.12 Total backscatter (NASC, Nautical Scattering Coefficient $m^2 * nm^{-2}$) measured in the upper 400 m of the water column during the high-resolution hydroacoustic grid north of Sao Vicente and Santa Luzia. Different colors indicate measurements made during night and day to be considered when investigating effects of diel vertical migration from deeper layers on the "surface" backscatter measured.

When crossing the seamounts, increased backscatter (indicating higher abundance of various organisms) was also measured on top of the seamounts as well as on the upper slopes (Fig. 5.13).

Post-processing and integration of hydroacoustic data are ongoing within the framework of a master thesis.

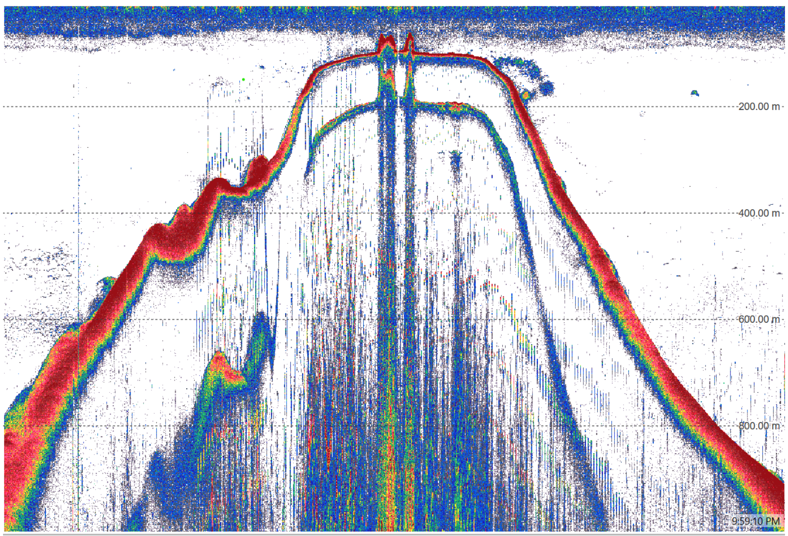

Fig. 5.13 Echogram recorded during the passage over the Nola Seamount top. Note the increased backscatter on top of the Seamount and on the upper slope.

5.4 Marine Pollution

5.4.1 Microplastics Samplings at Sea Surface

(E. Borchert, T. Hamm)

Introduction

Microplastic distribution in the Eastern Tropical North Atlantic is largely unknown as very few datasets in the region exist. This study aimed to provide information about microplastics (MP) distribution and concentration within this region by collecting samples along the cruise track. In addition, the abundance of microplastic particles inside mesoscale eddies was investigated to better understand the horizontal physical offshore transport processes of these particles. Macroplastics will also be characterized and their distribution and concentrations assessed to provide the environmental context for constraining interactions between macroplastics and microbial organisms.

Methods

Microplastic sampling was carried out using a Neuston catamaran (mouth opening height x width = 40 x 70 cm) mounted to a 3m long net (mesh size = 300 µm) ended by a 30 x 10 cm^2 cod-end and a flowmeter placed in the center of the trawl opening. The catamaran was deployed along the cruise and towed horizontally to collect sea surface microplastics (Figure 5.14).

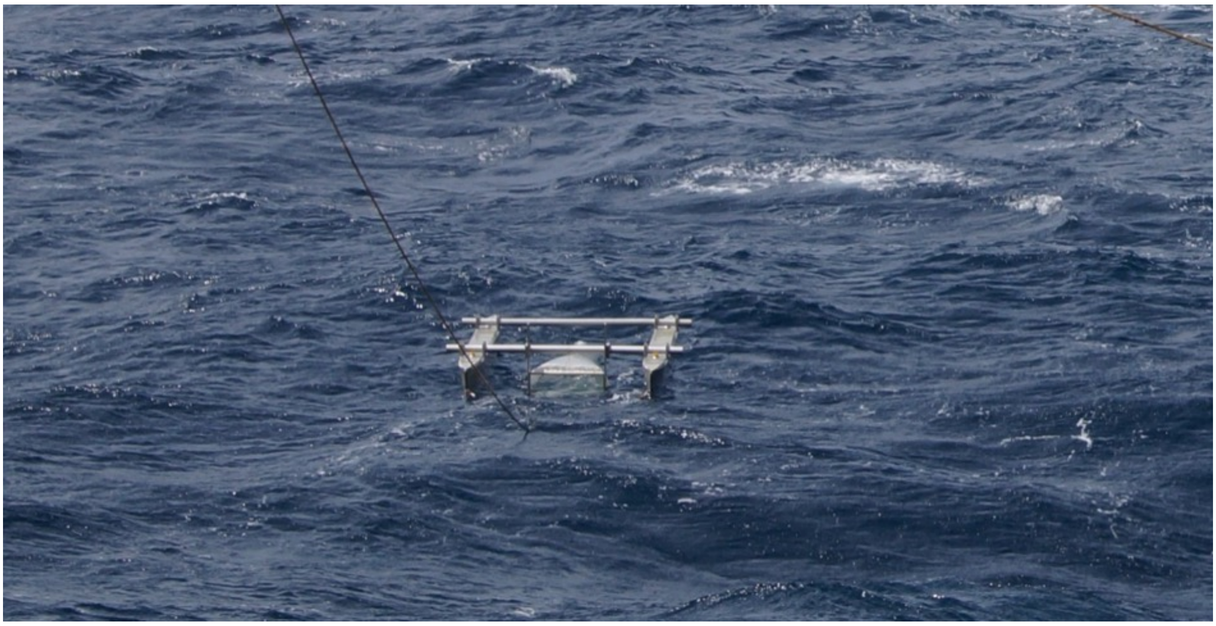

Fig. 5.14 Catamaran being towed.

Each tow of the catamaran lasted for 20 mins with a total of 48 samples being collected across 16 stations. There were 3 tows per station. The volume of water sampled during each tow was estimated by multiplying the flowmeter difference by the flowmeter constant and area of the net opening submerged (i.e. half the total area of the net opening).

Once the Catamaran was out of the water, information on date, time, flowmeter value, latitude, longitude, depth, speed, and exact towing time was noted in sampling protocol.

At the end of each tow, the net was washed and rinsed while hanging along the side of the vessel, and cod-end detached into an aluminum container and transported to the laboratory (Fig. 5.15).

Fig. 5.15 Removal of net cod-end after a completed tow.

Cod-ends were washed inside out with filtered seawater and sieved using a metal sieve (300 µm) for initial visual sorting of potential microplastics (PMP) under a magnification lamp. The remaining part of the sample was then washed off into a weck glass and frozen at -20 ºC to be later fixed with formaldehyde for analysis on land. PMPs found are stored in labeled safe seal tubes (0.6ml) for analysis with the hyperspectral imaging (HSI) camera (SPECIM FX17, SPECIM, Spectral Imaging Ltd., Finland). Aluminum containers used were rinsed with filtered seawater and maintained closed before and after the sampling to avoid contamination. Cod-ends were also decontaminated before use in the next sampling. Also, subsamples of potential contamination sources from the vessel and the hose used in the laboratory were taken.

Microplastic particles were measured onboard using the newly developed HSI camera system. The HSI operates with the Lumo scanner software, which makes a scan of a set of (plastic) particles prepared on a black microscopy slide. The black background helps the image recognition software to detect the particles as it reflects little radiation.

Table 5.3 Summary of Neuston catamaran trawls during MSM106.

D-ship	**Date**	**Time**	**Latitude (start)**	**Longitude (start)**
MSM106_16	02.03.2022	12:24	17°15.855'N	024°29.852'W
MSM106_17	02.03.2022	22:56	17°35.754'N	024°14.158'W
MSM106_18	03.03.2022	13:21	18°20.005'N	023°46.149'W
MSM106_22	05.03.2022	6:06	22°54.212'N	020°49.397'W
MSM106_23	06.03.2022	12:45	26°03.364'N	017°47.429'W
MSM106_24	08.03.2022	2:44	29°12.918'N	015°30.045'W
MSM106_25	09.03.2022	11:30	34°34.793'N	013°09.400'W
MSM106_27	10.03.2022	16:45	38°43.892'N	011°26.328'W
MSM106_28	10.03.2022	23:35	37°53.927'N	011°32.263'W
MSM106_33	11.03.2022	17:38	37°54.466'N	011°34.957'W
MSM106_37	12.03.2022	16:24	39°37.546'N	011°28.362'W
MSM106_40	13.03.2022	13:13	41°15.085'N	011°40.278'W
MSM106_42	15.03.2022	10:03	47°14.658'N	006°49.191'W
MSM106_43	16.03.2022	8:26	49°20.054'N	003°43.945'W
MSM106_44	17.03.2022	10:27	51°46.808'N	002°46.718'E
MSM106_45	17.03.2022	15:12	52°13.491'N	003°34.224'E

Preliminary results and outlook

During MSM106, 48 Neuston catamaran deployments were realized at 16 stations (Table 5.3). Three deployments were in the wake behind the ship due to difficult weather conditions and this may influence microplastic concentrations in these samples. Two microplastic items were collected and stored in RNAlater for DNA and RNA extraction and sequencing of the metagenome. 155 particles were picked from the sample on board and considered potential microplastics. The particles were then analysed with the HSI camera to investigate the polymer type. Of the 155 particles, 73 were identified as not being plastic, 58 were polyethylene, 23 were polypropylene and one particle was polystyrene.

The organic components of the samples will be digested in the laboratory and the leftover material will again be tested for microplastics with the HSI camera to determine all plastic particles >300 µm in the collected samples. This will be done in a plastic-free environment to prevent contamination of the samples.

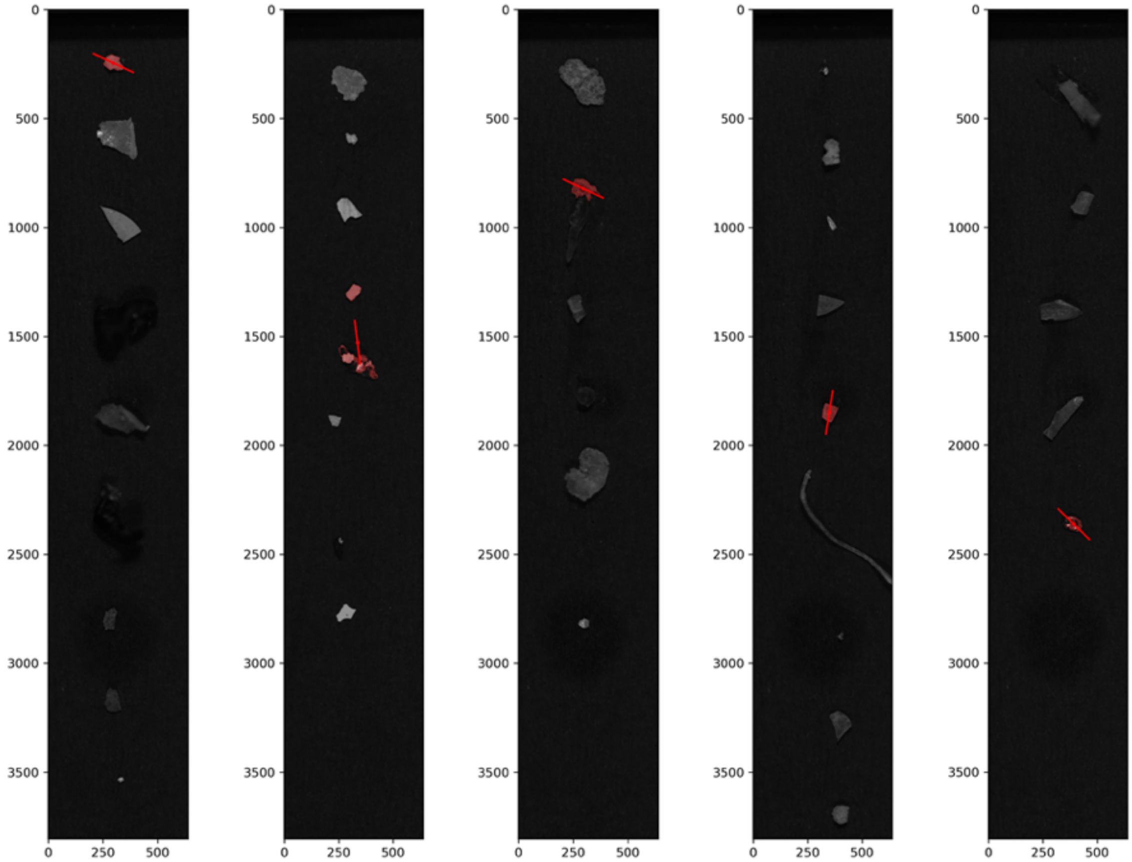

Fig. 5.16 Examples of scanned slides from the HSI camera system.

6 Station List

6.1 Overall Station List

Station	Date in 2022	Time [UTC]	Device	Latitude	Longitude	Water Depth (m)	Remarks
MSM106_1-1	26-Feb	12:24	EK80	16°56.985' N	025° 19.701' W	76	Begin calibration
MSM106_2-1	26-Feb	15:41	MOOR	17° 11,440' N	025° 36.055' W	194	Anchor, releaser & 3 floats in water
MSM106_2-2	26-Feb	17:26	WVGL	17° 11.183' N	025° 36.098' W	709	
MSM106_3-1	26-Feb	18:41	ADCP	17° 15.307' N	025° 36.888' W	33	COG 152°, v=10kn
MSM106_3-2	26-Feb	20:11	ADCP	17° 12.091' N	025° 26.504' W	0	COG=332°, v=10kn
MSM106_3-3	26-Feb	21:23	ADCP	17° 16.833' N	025° 25.089' W	0	COG=243°, v=10kn
MSM106_4-1	27-Feb	02:03	ADCP	17° 39.458' N	025° 29.871' W	62	COG=090°, v=10kn
MSM106_5-1	27-Feb	18:49	ADCP	16° 57.397' N	024° 57.386' W	87	v=10kn
MSM106_6-1	28-Feb	13:25	ADCP	16° 53.697' N	024° 30.051' W	67	COG=000°, v=10kn
MSM106_7-1	01-Mar	00:01	CTD	17°46.224' N	025° 02.816' W	57	
MSM106_7-2	01-Mar	00:04	GSCRS	17° 46.224' N	025° 02.814' W	65	
MSM106_7-3	01-Mar	01:32	PELAGIOS	17° 46.225' N	025° 02.816' W	3565	
MSM106_8-1	01-Mar	06:17	CTD	17° 38.413' N	024° 54.604' W	58	
MSM106_8-2	01-Mar	06:21	GSCRS	17° 38.413' N	024° 54.604' W	67	
MSM106_9-1	01-Mar	08:50	CTD	17° 30.654' N	024° 46.466' W	67	
MSM106_9-2	01-Mar	09:06	GSCRS	17° 30.692' N	024° 46.428' W	66	
MSM106_10-1	01-Mar	11:21	CTD	17° 22.882' N	024° 38.312' W	65	
MSM106_10-2	01-Mar	11:26	GSCRS	17° 22.883' N	024° 38.313' W	73	
MSM106_11-1	01-Mar	13:34	CTD	17° 15.108' N	024° 30.181' W	63	
MSM106_11-2	01-Mar	13:44	GSCRS	17° 15.108' N	024° 30.181' W	68	
MSM106_11-3	01-Mar	14:50	PELAGIOS	17° 15.108' N	024° 30.183' W	60	
MSM106_12-1	01-Mar	18:37	CTD	17° 07.324' N	024° 22.027' W	61	
MSM106_12-2	01-Mar	19:08	GSCRS	17° 07.325' N	024° 22.027' W	63	
MSM106_13-1	01-Mar	20:53	CTD	16° 59.561' N	024° 13.901' W	0	
MSM106_13-2	01-Mar	21:02	GSCRS	16° 59.561' N	024° 13.903' W	0	
MSM106_14-1	01-Mar	23:04	CTD	16° 51.782' N	024° 05.782' W	0	
MSM106_14-2	01-Mar	23:15	GSCRS	16° 51.782' N	024° 05.783' W	0	
MSM106_15-1	02-Mar	01:06	CTD	16° 44.163' N	023° 57.824' W	0	
MSM106_15-2	02-Mar	02:05	GSCRS	16° 44.162' N	023° 57.825' W	0	
MSM106_16-1	02-Mar	06:43	PELAGIOS	17° 15.111' N	024° 30.178' W	0	
MSM106_16-2	02-Mar	09:54	MSN	17° 15.104' N	024° 30.171' W	0	
MSM106_16-3	02-Mar	12:24	NEMICAT	17° 15.072' N	024° 30.196' W	0	
MSM106_16-4	02-Mar	14:17	IKMT	17° 15.237' N	024° 30.084' W	0	
MSM106_16-5	02-Mar	17:09	FLOAT	17° 15.143' N	024° 30.183' W	0	
MSM106_17-1	02-Mar	19:57	CTD	17° 35.013' N	024° 14.872' W	0	

MSM106_17-2	02-Mar	20:01	GSCRS	17° 35.013' N	024° 14.872' W	0	
MSM106_17-3	02-Mar	22:56	NEMICAT	17° 35.079' N	024° 14.816' W	3591	
MSM106_17-4	03-Mar	00:25	MSN	17° 37.817' N	024° 12.222' W	0	
MSM106_17-5	03-Mar	02:36	MSN	17° 42.348' N	024° 09.099' W	0	
MSM106_17-6	03-Mar	04:57	PELAGIOS	17° 46.990' N	024° 06.365' W	0	
MSM106_18-1	03-Mar	12:04	CTD	18° 19.236' N	023° 46.720' W	3707	
MSM106_18-2	03-Mar	12:31	GSCRS	18° 19.236' N	023° 46.718' W	0	
MSM106_18-3	03-Mar	13:21	NEMICAT	18° 19.271' N	023° 46.691' W	0	
MSM106_18-4	03-Mar	14:37	MSN	18° 21.873' N	023° 44.784' W	0	
MSM106_18-5	03-Mar	16:31	PELAGIOS	18° 25.520' N	023° 42.234' W	0	
MSM106_19-1	04-Mar	10:04	CTD	20° 22.540' N	022° 29.709' W	0	
MSM106_19-2	04-Mar	10:15	GSCRS	20° 22.540' N	022° 29.708' W	0	
MSM106_19-3	04-Mar	10:31	PLA	20° 22.587' N	022° 29.653' W	0	
MSM106_19-4	04-Mar	11:14	FLOAT	20° 22.744' N	022° 29.484' W	0	
MSM106_20-1	04-Mar	20:01	FLOAT	21° 33.328' N	021° 43.765' W	0	
MSM106_21-1	05-Mar	05:03	IKMT	22° 51.987' N	020° 52.366' W	0	
MSM106_21-2	05-Mar	06:06	NEMICAT	22° 53.657' N	020° 50.160' W	0	
MSM106_21-3	05-Mar	07:32	CTD	22° 55.640' N	020° 47.481' W	0	
MSM106_21-4	05-Mar	07:34	GSCRS	22° 55.639' N	020° 47.480' W	0	
MSM106_21-5	05-Mar	07:55	PLA	22° 55.640' N	020° 47.480' W	0	
MSM106_21-6	05-Mar	08:37	FLOAT	22° 55.650' N	020° 47.441' W	0	
MSM106_22-1	05-Mar	17:24	FLOAT	24° 13.220' N	019° 58.704' W	0	
MSM106_23-1	06-Mar	09:01	MSN	25° 59.335' N	017° 50.241' W	0	
MSM106_23-2	06-Mar	10:25	PELAGIOS	26° 01.865' N	017° 48.486' W	0	
MSM106_23-3	06-Mar	12:08	CTD	26° 02.540' N	017° 48.052' W	0	
MSM106_23-4	06-Mar	12:17	GSCRS	26° 02.540' N	017° 48.052' W	0	
MSM106_23-5	06-Mar	12:45	NEMICAT	26° 02.594' N	017° 48.010' W	0	
MSM106_24-1	07-Mar	22:33	CTD	29° 10.013' N	015° 30.013' W	0	
MSM106_24-2	07-Mar	23:01	GSCRS	29° 10.013' N	01° 30.013' W	3609	
MSM106_24-3	08-Mar	01:39	MSN	29° 10.283' N	015° 30.013' W	3609	
MSM106_24-4	08-Mar	02:44	NEMICAT	29° 12.069' N	015° 30.046' W	3609	
MSM106_24-5	08-Mar	04:21	IKMT	29° 15.735' N	015° 30.045' W	3610	
MSM106_25-1	09-Mar	09:03	CTD	34° 31.961' N	013° 07.178' W	0	
MSM106_25-2	09-Mar	09:25	GSCRS	34° 31.960' N	013° 07.178' W	4424	
MSM106_25-3	09-Mar	10:28	MSN	34° 32.039' N	013° 07.237' W	4424	
MSM106_25-4	09-Mar	11:30	NEMICAT	34° 34.070' N	013° 08.788' W	4406	
MSM106_26-1	10-Mar	04:00	ADCP	37° 28.215' N	011° 40.006' W	0	COG=360°, v=10kn
MSM106_26-2	10-Mar	04:00	EK80	37° 28.215' N	011° 40.006' W	0	COG=360°, v=10kn
MSM106_27-1	10-Mar	14:08	CTD	38° 43.829' N	011° 20.978' W	0	
MSM106_27-2	10-Mar	14:15	GSCRS	38° 43.830' N	011° 20.977' W	3965	

MSM106_27-3	10-Mar	15:11	MSN	38° 43.845' N	011° 21.163' W	4965	
MSM106_27-4	10-Mar	16:44	NEMICAT	38° 43.892' N	011° 26.155' W	4048	
MSM106_28-1	10-Mar	22:45	NEMICAT	37° 53.929' N	011° 28.412' W	0	
MSM106_28-2	11-Mar	00:10	CTD	37° 53.928' N	011° 32.261' W	5060	
MSM106_28-3	11-Mar	00:59	GSCRS	37° 53.928' N	011° 32.262' W	5060	
MSM106_28-4	11-Mar	01:34	MSN	37° 53.948' N	011° 32.546' W	5061	
MSM106_28-5	11-Mar	03:11	IKMT	37° 54.302' N	011° 36.690' W	5061	Ranger Sonardyne deployed
MSM106_29-1	11-Mar	05:46	CTD	37° 57.707' N	011° 55.055' W	0	
MSM106_29-2	11-Mar	06:35	GSCRS	37° 57.707' N	011° 55.055' W	0	
MSM106_30-1	11-Mar	08:03	CTD	38° 00.332' N	012° 09.741' W	0	
MSM106_30-2	11-Mar	08:56	GSCRS	38° 00.332' N	012° 09.740' W	0	
MSM106_31-1	11-Mar	10:45	CTD	38° 02.977' N	012° 24.881' W	4889	
MSM106_31-2	11-Mar	11:22	GSCRS	38° 02.977' N	012° 24.881' W	4891	
MSM106_32-2	11-Mar	11:58	EK80	38° 02.977' N	012° 24.881' W	0	COG=103°, v=10kn
MSM106_32-1	11-Mar	12:08	ADCP	38° 03.029' N	012° 25.042' W	0	COG=103°, v=10kn
MSM106_33-1	11-Mar	16:33	NEMICAT	37° 54.002' N	011° 34.162' W	0	
MSM106_34-1	11-Mar	20:05	CTD	37° 51.070' N	011° 17.263' W	5054	
MSM106_34-2	11-Mar	20:46	GSCRS	37° 50.958' N	011° 17.350' W	5055	
MSM106_35-1	11-Mar	23:07	CTD	37° 48.136' N	011° 00.324' W	5038	
MSM106_35-2	11-Mar	23:19	GSCRS	37° 48.137' N	011° 00.326' W	5038	
MSM106_36-1	12-Mar	02:14	CTD	37° 45.185' N	010° 43.299' W	5013	
MSM106_36-2	12-Mar	02:41	GSCRS	37° 45.185' N	010° 43.300' W	5012	
MSM106_37-1	12-Mar	13:51	MSN	39° 35.048' N	011° 20.362' W	4821	
MSM106_37-2	12-Mar	15:35	NEMICAT	39° 36.594' N	011° 24.751' W	4684	
MSM106_37-3	12-Mar	16:55	CTD	39° 37.548' N	011° 28.364' W	4412	
MSM106_38-1	12-Mar	23:06	ADCP	40° 32.383' N	011° 38.994' W	5160	
MSM106_38-2	12-Mar	23:06	EK80	40° 32.383' N	011° 38.994' W	5160	
MSM106_39-1	13-Mar	08:49	ADCP	41° 14.992' N	012° 18.248' W	5103	
MSM106_39-2	13-Mar	08:49	EK80	41° 14.992' N	012° 18.248' W	5103	
MSM106_40-1	13-Mar	12:00	CTD	41° 14.996' N	011° 39.006' W	3109	
MSM106_40-2	13-Mar	12:33	GSCRS	41° 14.996' N	011° 39.008' W	3020	
MSM106_40-3	13-Mar	13:13	NEMICAT	41° 15.089' N	011° 39.251' W	3164	
MSM106_40-4	13-Mar	14:31	MSN	41° 16.776' N	011° 42.890' W	3438	
MSM106_41-1	14-Mar	12:58	CTD	44° 05.419' N	009° 10.371' W	0	
MSM106_41-2	14-Mar	13:07	GSCRS	44° 05.419' N	009° 10.371' W	0	
MSM106_42-1	15-Mar	09:01	CTD	47° 14.623' N	006° 49.085' W	2907	
MSM106_42-2	15-Mar	09:33	GSCRS	47° 14.624' N	006° 49.085' W	2908	
MSM106_42-3	15-Mar	10:03	NEMICAT	47°14.658' N	006° 49.191' W	2903	
MSM106_42-4	15-Mar	11:20	IKMT	47° 16.026' N	006° 53.500' W	3605	Ranger Sonadyne deployed

MSM106_43-1	16-Mar	08:02	CTD	49° 19.925' N	003° 43.656' W	87	
MSM106_43-2	16-Mar	08:08	GSCRS	49°19.925' N	003° 43.658' W	86	
MSM106_43-3	16-Mar	08:19	NEMICAT	49° 19.925' N	003° 43.658' W	86	
MSM106_43-4	16-Mar	09:48	MSN	49° 21.187' N	003° 48.211' W	87	
MSM106_44-1	17-Mar	10:27	NEMICAT	51° 46.808' N	002° 46.718' E	38	
MSM106_44-2	17-Mar	10:32	GSCRS	51° 46.871' N	002° 47.015' E	35	
MSM106_45-1	17-Mar	15:12	NEMICAT	52° 13.491' N	003° 34.224' E	28	
MSM106_45-2	17-Mar	15:46	GSCRS	52°15.024' N	003° 36.334' E	33	

Gear Coding:

CTD:	CTD rosette sampler
MSN:	Multinet
PELAGIOS:	PELAGIOS towed camera
MOOR:	Mooring operations (deployment)
ADCP:	Acoustic Doppler Current Profiler sections (75 kHz)
EK80:	SIMRAD EK80 Echosounder (WBT Mini, 38/200 kHz)
WVGL:	Autonomous surface vehicle (SV3 Wave Glider)
FLOAT:	Argo Float deployment
IKMT:	Isaacs-Kid Midwater Trawl Net
GSCRS:	Garrett Screen
NEMICAT:	Neuston Catamaran Trawl Net
PLA:	Small plankton net (handheld)

7 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 MSM106 will be stored at the Kiel data portal (OSIS) and Elements (Video & image data), respectively, and remained proprietary for the PIs and participants of this cruise. Each station was logged as an event file. All final data are being submitted to PANGAEA within approx. 2 years after the cruise, i.e. by spring 2024 at the latest. Zooplankton samples collected during the cruise will be digitized using the ZooScan method and sorted/archived on Ecotaxa. Likewise, UVP5 particle and image data are already available on Ecotaxa (https://ecotaxa.obs-vlfr.fr/prj/5569) and Ecopart (https://ecopart.obs-vlfr.fr/).

Table 7.1 Overview of data availability

Type	Database	Available	Free Access	Contact
CTD data	OSIS → PANGAEA	Dec 2022	Dec 2024	gkrahmann@geomar.de
ADCP data	OSIS → PANGAEA	Dec 2022	Dec 2024	gkrahmann@geomar.de
Thermosalinograph data	OSIS → PANGAEA	Dec 2022	Dec 2024	mschlundt@geomar.de
Bottle data (biogeochemistry)	OSIS → PANGAEA	Mar 2023	Mar 2025	bfiedler@geomar.de
Video data (PELAGIOS)	Elements → PANGAEA	Mar 2023	Mar 2025	hhoving@geomar.de
Zooplankton data	Ecotaxa → PANGAEA	Mar 2023	Mar 2025	hhauss@geomar.de
Hydroacoustic biomass data	PANGAEA	Mar 2023	Mar 2025	matthias.schaber@thuenen.de
Microplastic data	OSIS → PANGAEA	Mar 2023	Mar 2025	eborchert@geomar.de
UVP5 particle data	Ecopart	Mar 2022	Mar 2024	hhauss@geomar.de
UVP5 image data	https://ecotaxa.obs-vlfr.fr/prj/5569	Mar 2022	Mar 2024	hhauss@geomar.de

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10 Major Abbreviations

AC	= AntiCyclonic Eddy
ACME	= AntiCyclonic Modewater Eddy
ADCP	= Acoustic Doppler Current Profiler
CE	= Cyclonic Eddy
CDOM	= Chromophoric Dissolved Organic Matter
CRM	= Certified Reference Material
CTD/RO	= CTD Rosette
CVOO	= Cape Verde Ocean Observatory
DIC	= Dissolved Inorganic Carbon
DOM	= Dissolved Organic Matter
EBUS	= Eastern Boundary Upwelling Systems
ESTOC	= European Station for Time Series in the Ocean Canary Islands
FLOAT	= Argo Float
GSCRS	= Garrett Screen Sampler
IKMT	= Isaacs-Kid Midwater Trawl Net
MOOR	= Mooring (Deployment)
MSN	= Multiple Opening/Closing Net (Multi Net)
NE	= North-East
NEMICAT	= Neuston Catamaran Trawl Net
OMZ	= Oxygen Minimum Zone
REEBUS	= Role of Eddies for the Carbon Pump in Coastal upwelling Areas
SML	= Sea Surface Microlayer
TA	= Total Alkalinity
TSG	= Thermosalinograph
vmADCP	= Vessel-mounted Acoustic Doppler Current Profiler
UVP	= Underwater Vision Profiler
WASCAL	= West African Science Service Centre on Climate Change and Adapted Land Use
WVGL	= Wave Glider (Deployment)

11 Appendices

11.1 Pictures of Scientific Crew

Fig. 11.1 Scientific cruise participants of MARIA S. MERIAN MSM106 expedition (leg1).

Fig. 11.2 Scientific cruise participants of MARIA S. MERIAN MSM106 expedition (leg2).

11.2 Oceanographic Mooring

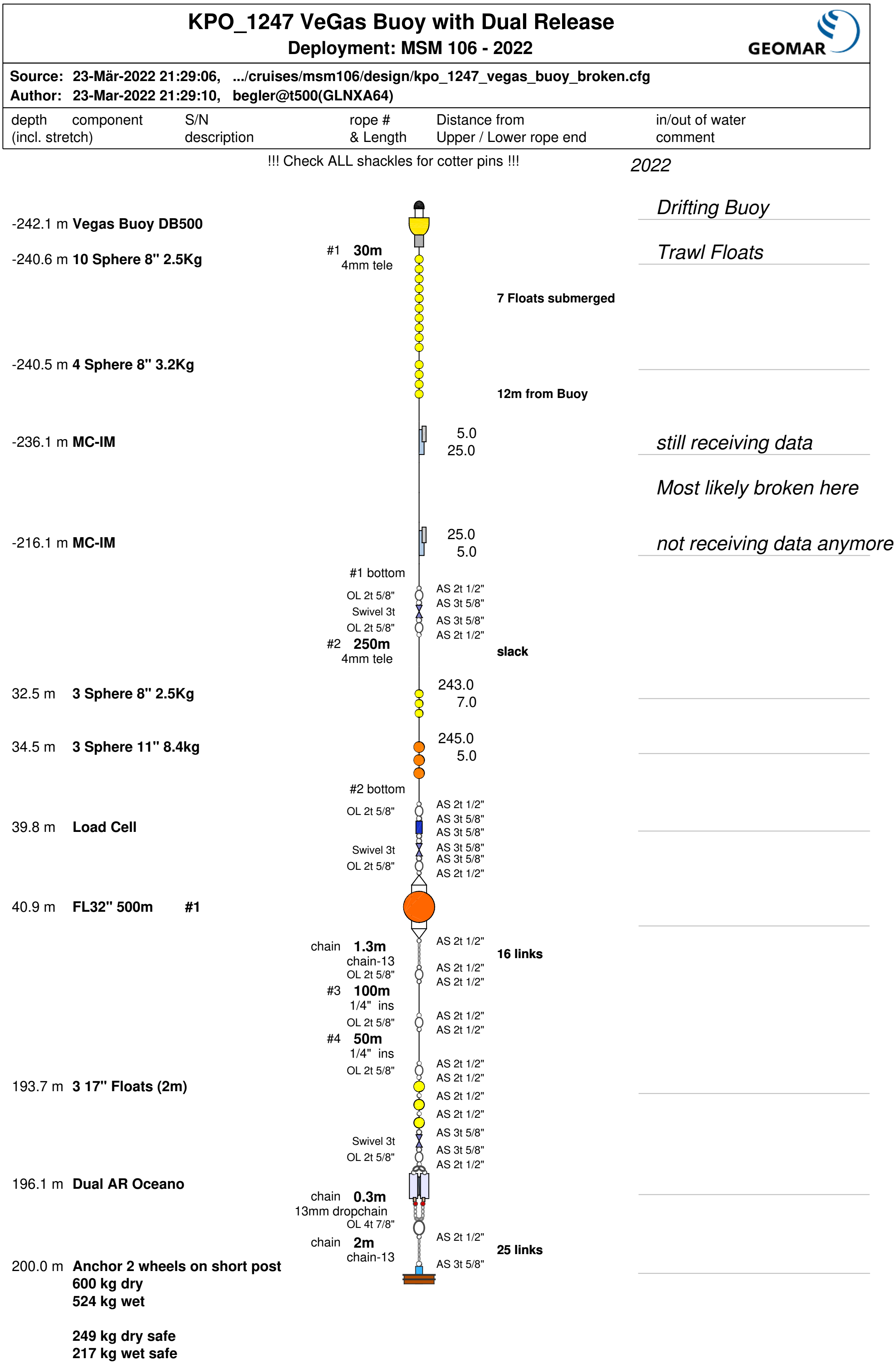

Fig. 11.3 Schematic of the mooring which was deployed during MSM106 at Nola Seamount.