METEOR-Berichte

Benthic element cycling, fluxes and transport of solutes across the benthic boundary layer in the Mauritanian oxygen minimum zone, (SFB 754).

Cruise No. M107

May 30 – July 03, 2014,
Fortaleza (Brazil) – Las Palmas (Spain)

S. Sommer, M. Dengler, T. Treude

Editorial Assistance:

DFG-Senatskommission für Ozeanographie
MARUM – Zentrum für Marine Umweltwissenschaften der Universität Bremen

2015

The METEOR expeditions are funded by the *Deutsche Forschungsgemeinschaft (DFG)* and the *Bundesministerium für Bildung und Forschung (BMBF)*.

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Citation: S. Sommer, M. Dengler, T. Treude (2015) Benthic element cycling, fluxes and transport of solutes across the benthic boundary layer in the Mauritanian oxygen minimum zone, (SFB754) – Cruise No. M107 – May 30 – July 03, 2014 – Fortaleza (Brazil) – Las Palmas (Spain). METEOR-Berichte, M107, 54 pp., DFG-Senatskommission für Ozeanographie, DOI:10.2312/cr_m107

ISSN 2195-8475

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1 Summary

A detailed multi-disciplinary research program was conducted at the Mauritanian oxygen minimum zone (OMZ). Investigations were primarily performed along a depth transect at 18°20' N. In this area upwelling of cold, nutrient-rich deep water is strongly seasonal, predominating from April until December. Major aim was to advance understanding of how OMZs are maintained and to determine feedbacks of benthic nutrient release on the currently expanding Mauritanian OMZ under such conditions. Major focus was on (i) variability of benthic nutrient release in response to hydrodynamic forcing and regional differences in geochemistry, (ii) diapycnal and advective fluxes of nutrients, trace metals, and radio-tracer between the sediments and the stratified interior ocean as well as their entrainment into the surface mixed layer and (iii) processes involved in the respective benthic and pelagic N, Fe, and P cycles. The working program in the water column comprised a total of 73 CTD casts, 38 microstructure CTD- and 17 in situ pump deployments. Moorings and Glider were deployed at 18°20' N and 19°50' N. Furthermore, in the northern working area ADCP-transects and casts of Underway CTDs were conducted to follow upwelling-induced frontal systems. In situ benthic fluxes of nutrients and oxygen were conducted using the Biogeochemical Observatories BIGO I and BIGO II comprising a total of 9 deployments. Further sediment samples for biogeochemical, investigations were obtained during the deployment of 22 casts of a video guided Multiple Corer (MUC). All deployments were successful and the envisaged data and samples were collected.

Zusammenfassung

Im Rahmen dieser Forschungsreise wurde ein multidisziplinäres Programm in der mauretanischen Sauerstoffminimumzone (SMZ) durchgeführt. Die Arbeiten fanden vorwiegend entlang eines Tiefenschnitts bei 18°20'N statt. In diesem Gebiet ist der Auftrieb von nährstoffreichem Tiefenwasser saisonal und ist von April bis Dezember schwach ausgeprägt. Zielsetzung dieser Reise war es unser Verständnis zur Aufrechterhaltung von SMZen zu erweitern und die Auswirkung von benthischen Rückkoppelungsmechanismen auf die sich gegenwärtig ausbreitende mauretanische SMZ unter schwachen Auftriebsbedingungen zu erfassen. Im Vordergrund der Untersuchungen stand i. die Variabilität der benthischen Rückführung von Nährstoffen in Abhängigkeit des hydrodynamischen Regimes sowie der Geochemie des Bodenwassers und der Sedimente; ii. die Erfassung von diapyknischen und advektiven Flüssen von Nährstoffen, Spurenmetallen, sowie von Radiotracern zwischen dem Sediment, der geschichteten Wassersäule und der durchmischten Oberflächenschicht; und iii. Erfassung von Prozessen, die am benthischen Umsatz von N, Fe und P beteiligt sind. Die Arbeiten in der Wassersäule umfassten insgesamt 73 CTD-, 38 Mikrostruktur CTD- sowie 17 in situ Pumpen-Einsätze. Ferner wurden Verankerungen entlang des Tiefenschnitts bei 18°20'N und 19°50'N ausgebracht und ein Glider Schwarm eingesetzt. Im nördlichen Arbeitsgebiet wurden zudem ADCP-Schnitte und Underway-CTDs eingesetzt um auftriebsbedingte Frontensysteme zu erfassen. Benthische Flüsse von Nährstoffen und Sauerstoff wurden mittels 9 Einsätzen von BIGO I und BIGO II (Biogeochemical Observatories) erfasst. Weitere Sedimentproben für biogeochemische, Untersuchungen wurden während 22 Einsätzen eines TV Multicorers (MUC) gewonnen. Die Einsätze verliefen hervorragend somit steht das angestrebte Datenmaterial zur Verfügung.

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3 Research Program

Oxygen Minimum Zones are key regions for the biogeochemical cycling of major elements. Questions arise as to how OMZs are maintained and what are the potential feedbacks of benthic nutrient release on the presently observed spreading of OMZs. The research cruise to the Mauritanian OMZ was conducted within the context of the 2nd phase of the Kiel SFB-754.

The objectives were:

a. to determine variability of benthic nutrient release in response to the hydrodynamic forcing and regional differences in bottom water levels of oxygen (O_2), nitrate (NO_3^-), nitrite (NO_2^-), and sedimentary carbon content (C_{org});

b. to quantify diapycnal and advective fluxes of ammonium (NH_4^+), phosphate (PO_4^3), Fe, Si, and radium isotopes across the benthic boundary layer (BBL) into the stratified interior ocean and the surface mixed layer;

c. to investigate microbial processes involved in the sediment and the water column N (e.g. N-fixation, denitrification, anammox), Fe, and P cycles;

d. to study the distribution of trace metals;

e. to study the influence of viruses on pelagic biogeochemical processes in the OMZ;

The above objectives were approached by synoptically coupling in situ benthic fluxes, current measurements using different types of lander and moorings, microstructure shear and temperature profiles, CTD measurements including high vertical resolution water column sampling and Gliders. The working areas were at 18°20’N and to a minor extent at 19°50’N (Figure 3.1). Along this depth transect seven stations at water depths of 47, 91, 171, 236, 412, 787 and 1095 m were designated as main sites for which a coherent data set of all physical, biogeochemical and microbiological measurements from the different working groups will become available (Figure 3.2). The length of this transect was about 26 nm. Time series measurements of currents and physical properties of the water column were conducted using different moorings in addition to 2 benthic mini-landers that were equipped with upward-looking ADCPs and a Glider swarm. Measurements of the microstructure and turbulent mixing of the water column were conducted using a shipboard operated microstructure CTD (MSS). Water sampling for nutrients, microbiology, particles as well as trace metals based on CTD water sampling rosette casts and casts of a specific trace metal CTD. The measurements in the water column were supplemented with deployments of in situ pumps for radiotracer measurements. The benthic program included in situ flux measurements using BIGO I and BIGO II, each equipped with two benthic flux chambers as well as a transecting profiling lander. Sediment samples for geochemical, microbiological and radiotracer measurements were taken using a video guided multiple corer. Sediments recovered from the BIGO flux chambers were also used for these analyses. Further sediment samples were taken using the MUC for ex situ laboratory incubations to simulate anoxic conditions for Mauritanian margin sediments and the consequences for the mobilization of iron and phosphorous.

In addition to the southern working area at 18°20’ N further oceanographic measurements were conducted at the northern working area at 19°50’ N.

The results of this cruise will be interpreted in conjunction with data from a previous cruise to the Mauritanian OMZ that were collected in March/April 2011 (Cruise MSM 17/4, PI O. Pfannkuche) during upwelling conditions. This cruise took place just at the transition between upwelling and non-upwelling conditions, which was expected to affect benthic and pelagic biogeochemical element turnover.

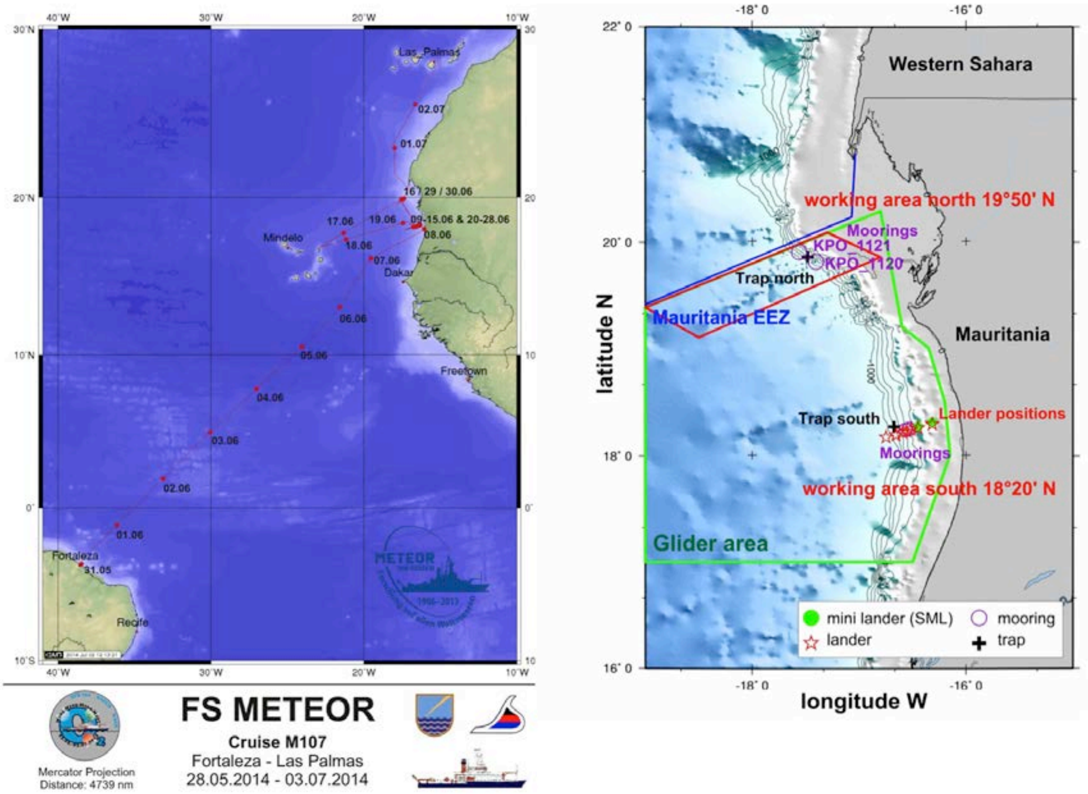

Fig. 3.1 Track chart and working areas investigated during of R/V METEOR Cruise M107 showing the southern and northern working areas at 18°20' N and 19°50' N. Major focus was on the depth transect at 18°20' N.

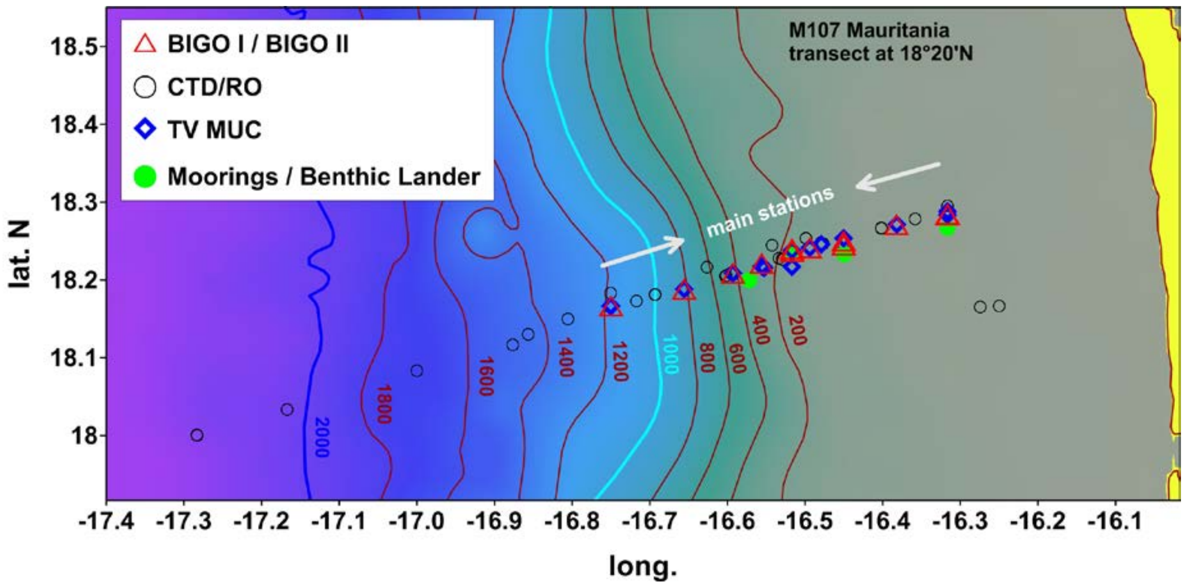

Fig. 3.2 Detailed station map of the 18°20' N working area. The entire depth-transect covers water depths of 70 to 1500 m and a horizontal distance of about 45 nm.

We deviated from the proposed working program as no benthic works were conducted in the northern working area. The departure from Fortaleza was delayed due to customs. Furthermore, due to an injury of a crew-member who needed a fast transfer into a German hospital we were forced to sail to the Cape Verde islands. In order to compensate for this loss of station time, it was decided to focus on the working program at the southern working area. As planned from this area, a complete and coherent database was successfully obtained. Furthermore, in order to conduct measurements of the trace metal distribution in Mauritanian waters, we deviated from the originally proposed measurements of NO_3^- micro-gradients in the sediment surface. This was due to the establishment of a new subproject within the Kiel SFB 754 and giving this subproject the opportunity to participate in this cruise.

4 Narrative of the Cruise

(Stefan Sommer)

On the 28th May a small group of scientists boarded the RV METEOR to prepare loading and to organize the visit of the vice-minister from the BMBF, Dr. Thomas Rachel, and representatives of the Brazilian German embassy of the research vessel. Prof. Dr. P. Brand, chief scientist of the previous cruise M106, and Dr. S. Sommer reported about their research activities. In the evening a reception took place hosting the vice-minister, Brazilian politicians and scientists as well as members of the Brazilian DAAD. On the 29th May the remaining scientific crew arrived at RV Meteor and loading of scientific gear began. Due to delays caused by the Brazilian customs the departure was delayed until Saturday 31st May at 11:00 local time. The following transit across the Atlantic lasted until 08th June 13:00 UTC when we reached Nouakchott and Mr. Mamadou Ba, the Mauritanian observer (IMROP, Institut Mauritanien de Recherche Océanographiques et des Peches), boarded. During the transit outside the Brazilian EEZ various underway measurements were conducted. A tow fish was deployed to continuously sample surface water at a water depth of 5m. The thermosalinograph permanently recorded surface water temperature and salinity. Additionally, every 2 hours the water column was hydrographically investigated using an underway-CTD (u-CTD). These measurements were supplemented by current measurements using the shipboard ADCP and continuous pCO_2 measurements of the surface water. Furthermore, the laboratories were established and the lander systems prepared. The scientific team of the M107 cruise was very interdisciplinary ranging from physical oceanography deploying CTD/water sampling rosette, microstructure CTD, glider, and moorings to benthic and pelagic biogeochemistry as well as microbiology and virology. Benthic biogeochemistry and microbiology involved the deployment of the benthic observatories BIGO in order to measure solute fluxes inside chambers and a TV-guided multiple corer (TV-MUC) to retrieve undisturbed sediments for porewater analyses. Pelagic biogeochemistry relied on casts of the CTD water sampling rosette and the trace metal CTD. Furthermore, in situ pumps were deployed for tracer geochemistry. In addition to these sampling activities, ex situ experiments and incubations were conducted on board.

Until the 15th June our research activities focused on a depth transect in the southern working area at 18°20'N. This working area comprised 7 major stations in water depths of 1095, 787, 412, 236, 171, 91, and 47 m where all instruments were deployed in order to obtain a spatially coherent data set. The length of this transect was ca. 26 nm. For physical and biogeochemical measurements the depth transect extended to a water depth of about 2200 m covering a distance of ca. 58 nm from the shallowest to the deepest station. At the beginning of this first working period at 18°20'N the moorings KPO 1118 and KPO 1119 as well as the benthic observatories Deep-sea Observation System (DOS) and Physical Oceanography Lander (POZ) were anchored at the seafloor in water depths of 356, 164, 91 and 41 m to synoptically record the current regime. In the following days the benthic observatories BIGO I and BIGO II were deployed, beginning with the deepest stations at 1095, 787, and 412 m. At each of the BIGO stations the TV-MUC was deployed to obtain undisturbed surface sediment samples with about 40 cm sediment retrieval. From the sediments retrieved by the TV-MUC N-species, P, Fe, Si, TA, porosity, and water content were determined. Stable N-isotopes will be measured on selected samples. From the BIGO, which obtains water and sediment samples, nutrients (N-species, P, Fe, Si), pCO_2, DIC and TA were determined in the water samples.

Benthic works were predominantly conducted during the daytime, whereas the water column was mostly studied during the nighttime comprising the deployment of a CTD water sampling rosette, microstructure CTD and a trace metal CTD. The CTD water-sampling rosette was subsampled for measuring nutrients, N P fixation rates as well as DOM and partially nitrogen stable isotopes. Samples of the Trace Metal CTD were analyzed for trace metals. Furthermore, for the analysis of radiotracers (Ra, Th, U) in situ pumps were deployed at all major stations, which were mounted onto a wire and kept in the water for about 3 – 4 hours. Three gliders for the continuous measurements of physical parameters (temperature, conductivity), oxygen, nitrate (only one glider) and microstructure (only one glider) were deployed along the depth transect. Lastly a profiling lander (Profiler) was deployed to conduct in situ voltammetric measurements in the sediment. The profiler was further equipped with a "lab on a chip" (LOC) for short time series measurements (days) of nitrate and during one deployment of nitrite in conjunction with temperature, conductivity, pressure, oxygen and turbidity measured by a CTD (RBR Ltd. Canada).

On Sunday 15th June we left the southern working area and moved towards the northern working area, a distance of about 115 nm, where we deployed our third Mooring (KPO1121) in a water depth of 148 m. On Monday 16th June 13:00 we interrupted our research activities and headed towards the island Sal (Cape Verde Islands) in order to enable a fast transfer of a crew-member to Germany, who unfortunately suffered a serious injury. After a transit of about 70 hours we continued with our research activities in the southern working area with the recovery of a drifting sediment trap.

Until Friday 27th June research activities were continued in the southern working area as described above with the deployment of the BIGOs, TV-MUC, Profiler and in situ pumps during daytime and investigations in the water column during the nighttime. In addition to these activities a total of 6 floats were deployed in water depths of 2050 to 2200 m. After recovery of the moorings and the glider we finished our activities in this area at the 27th June and headed northwards. Unfortunately, the mooring KPO119 did not respond to hydro-acoustic signals and could not be recovered. We assume that this mooring was lost caused by fishing activities. Due to time constraints, predominantly ADCP- and u-CTD transects were conducted across frontal systems in the northern working area. We suffered a further setback with the mooring KPO1121, whose head-buoy was detached due to fishing activities. This buoy was then transferred by a trawler to Nouakchott and stored in the IMROP facility. First trials to locate the remaining mooring, which was still anchored at the bottom failed and only after increasing the search area considerably were we able to locate and retrieve it.

On the morning of Monday 30th June we finished our station work of M107 with the retrieval of the glider under very calm weather conditions. Subsequently we went to Nouakchott where we organized a handing-over of the head-buoy from IMROP at sea. Then we started our transit to Las Palmas (Spain) where bad weather conditions delayed our arrival until the afternoon of Thursday 3rd July. Our observer Mamadou Ba, who during the entire cruise was very helpful and supportive, left RV Meteor on the same evening. It was planned that the remaining scientists depart on the morning of 4th July, but due to our late arrival and problems with container logistics, a small group stayed until 5th July.

Despite the delays, we were able to successfully conduct our research at the southern working area, which was the main focus of our activities. However, the research in the northern working area was affected as almost no biogeochemical measurements were conducted in the water column. Nevertheless, a total of 9 BIGO- and 3 Profiler- deployments were conducted along the depth transect in the southern working area. In addition 22 TV-guided multiple corer casts were carried out to investigate the sediment geochemistry. Analyses of these results will provide a broad benthic biogeochemical database that will be interpreted in the context of water column physical and biogeochemical measurements based on 73 CTD casts, a multitude of micro-structure CTDs and u-CTD casts as well as on moorings and glider data. Furthermore these data will be carefully interpreted in comparison to the measurements made during the MS Merian cruise MSM 17/4.

5 Preliminary Results

5.1 Underway measurements during the transit from Brazil to Mauritania

(Marcus Dengler, Alice Pietri, Sören Thomsen)

Data were collected from June 1st to 8th June and again from June 28th to 29th 2014 using an underway CTD (uCTD). A total of 218 profiles were recorded by the instrument. From June 1st to 8th the system was used to survey the upper part of the water column while the ship crossed the tropical Atlantic from Brazil to Mauritania. The acquired data allow to observe the variability of the mixed layer and to identify low salinity lenses north of the equator. During this first period 76 profiles were recorded with an average depth of 350 m. The section across the Atlantic started at 0.5°S, 35.5°W and ended at 17.5°N, 17°W and was carried out with an average horizontal resolution of ~ 38.5 km. For the underway measurements using a towed Fish system deployed by C. Schlosser, see section 5.3.4. On the 28th June a frontal structure was detected in the thermohaline data recorded by the ship's Thermosalinograph off the coast of Mauritania at ~ 19.7°N, 17.6°W. In order to observe the vertical structure of this front and its variability it was crossed several times by the ship over the course of two days. During this time 141 casts were realized with the uCTD. A time delay of about 7 minutes between each profile was chosen in order to have the best possible horizontal resolution. The average depth of those profiles is 85 m with an average horizontal resolution of 1.5 km. A preliminary calibration was applied to the salinity data. A lagged temperature time series $T_c = T - \tau\, dT/dt$ was used to compute salinity. The best correction for the whole mission was $\tau = 0.09$ s (Figure 5.1.1).

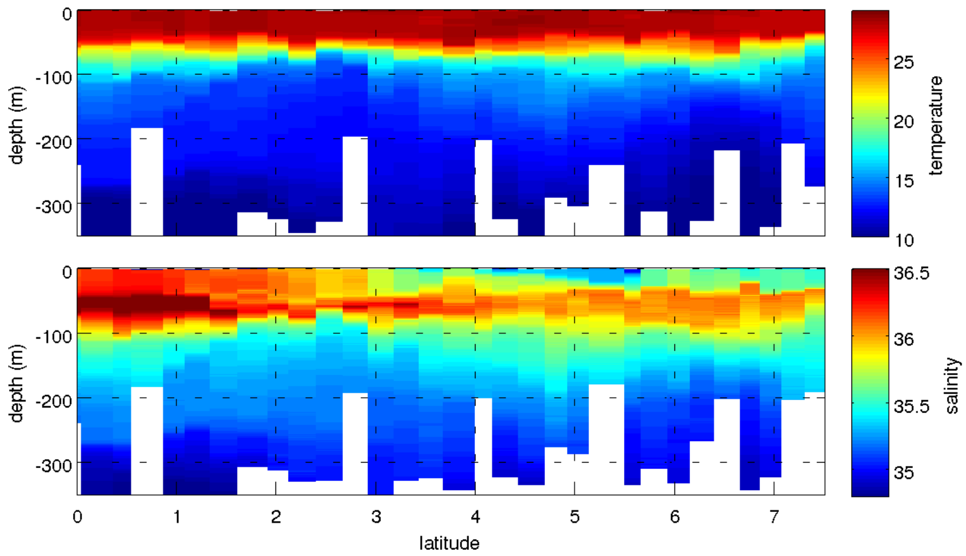

Fig. 5.1.1 Underway CTD temperature and salinity section from the equator to 7°N

5.2.1 Glider, moorings, oceanographic benthic lander

(Marcus Dengler, Sören Thomsen, Alice Pietri, Christian Begler)

Glider

An integral component of the measurement program of M107 was the use of autonomous measuring platforms (i.e. gliders) to measure hydrography, turbulence, and various biogeochemical parameters at high spatial resolution across the continental slope. Altogether, six Slocum gliders (ifm02, ifm03, ifm07, ifm12, ifm13 and ifm14) were deployed and retrieved during cruise M107 (Fig. 5.2.1.1, Table A1 in the Appendix). All gliders were equipped with temperature, conductivity, pressure, chlorophyll (chl-a), turbidity and oxygen sensors. In addition, ifm03, ifm07, ifm12 and ifm14 had a sensor for the measurement of colored dissolved organic matter (CDOM). Apart from the sensors built into the gliders, three gliders carried self-contained sensor packages mounted to the gliders' top: Ifm02 and ifm03 were equipped with a microstructure probe (MicroRider, Rockland Scientific) with two microstructure shear and two microstructure temperature sensors as well as fast-responding accelerometers while ifm13 was equipped with a nitrate sensor (Suna, Satlantic).

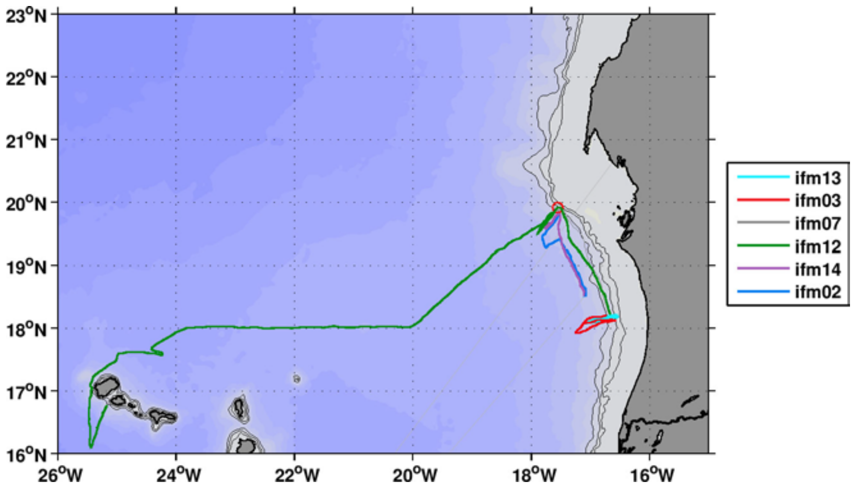

Fig. 5.2.1.1 Glider tracks are shown by color code. The red dot marks a mooring position in the northern working area at 19°50’ N. Image is taken from geomar.gliderweb.de.

At the beginning of cruise M107, 2 gliders (ifm03 and ifm13) were deployed at 18°N on June 9 and 12, respectively. They followed a transect perpendicular to the continental slope of about 70 km length and were recovered on June 27. Those two gliders supported the ship-based CTD and microstructure measurement program along the 18°20’ N transect. Figure 5.2.1.2 shows the salinity and oxygen concentration along one of the transects completed by ifm13. Oxygen presents high concentrations in the surface layer while deeper (from 50 to 200m depth), in the coastal area, it drops to a minimum (30 µmol l^{-1}). Both the salinity and the oxygen fields show patchiness and small-scale variability in the subsurface layer.

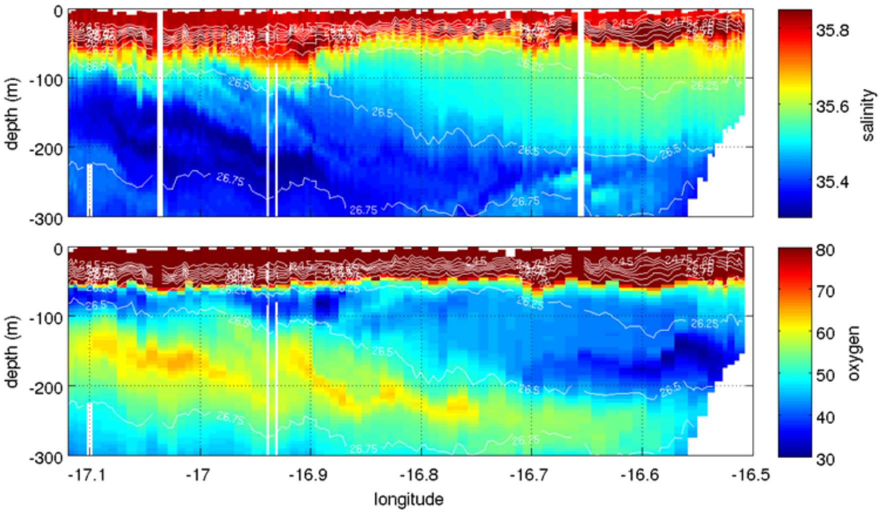

Fig. 5.2.1.2 Salinity and oxygen concentration (µmol l^{-1}) recorded by glider ifm13 along the southern transect (18°20’ N) from 15. to 18. June.

Moorings, oceanographic lander

A short-term mooring and oceanographic lander program was conducted at 18°20’N (Fig. 5.2.1.3) to investigate the variability of the boundary circulation and to study the generation and dissipation of non-linear internal waves. Additionally, two moorings were planned to be deployed at the continental slope at 20°N to observe submesoscale variability associated with an upwelling front. Of the 6 planned mooring and lander deployments, only 5 were carried out. Due to the unforeseen interruption of the station program around noon on 16 June and the constraints on the cruise time schedule associated with the travel to Sal, it was not possible to deploy KPO 1120 (Fig. 5.2.1.3). Additional setbacks of the mooring program came from fishery vessels. Five days after the deployment of KPO 1121, we were informed by a Latvian shipping company that their trawler Marshal Novikov had caught the top flotation including instruments of the mooring. With the support of the Mauritanian observer, we were able to retrieve the flotation and the instruments from Nouadibou, Mauritania where they were left by the trawler. The remaining equipment of KPO 1121 was also recovered 8.6 nm southwest of the deployment position in 1365m water depth, 700m deeper than its target depth, after a few hours of searching using hydrophones.

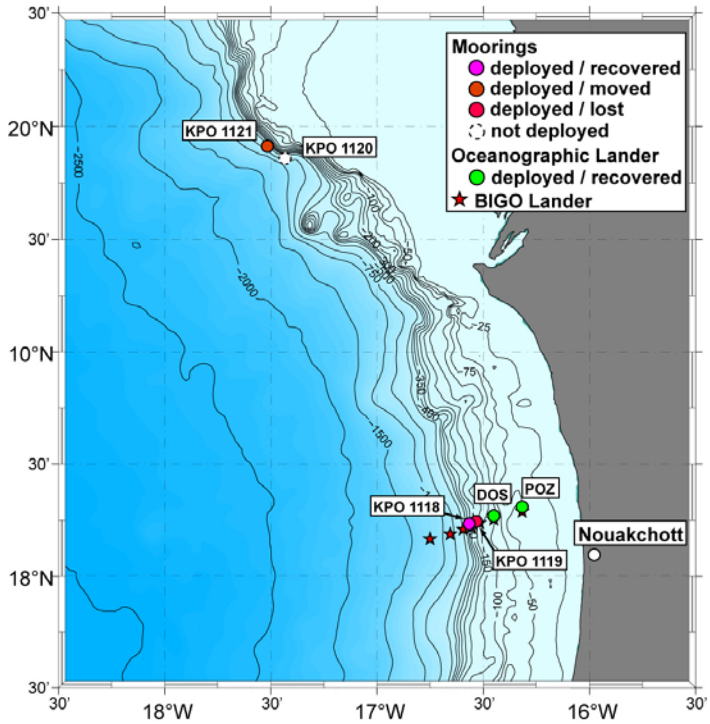

Fig 5.2.1.3 Map of moorings and oceanographic lander positions during cruise M107. The mooring program was hampered due to mooring displacements by trawlers and due to an unforeseen visit to Sal, Cape Verde. Details of the data recording are given in Table A2 and A3 (Appendix).

Mooring KPO 1119 was not recovered during the cruise. No signal from the releasers was received at the mooring position during recovery attempt 14 days after deployment. Stress marks in the sediments observed with video-guided MUC suggested northward displacement. However, a search for the mooring (8h) using hydrophones remained unsuccessful, despite the help of FS Walther Herwig, which contributed to the search using its acoustic fish finder device.
All instruments of the remaining mooring and the two oceanographic landers were recovered and showed complete data records. Details of the mooring and lander instrumentation and available data sets are listed in Table A2 and A3 in the appendix.

Preliminary results: Time series of velocity from the moorings/landers along 18°20’N showed a coherent picture of the boundary circulation during the end of the upwelling season in June. The mean alongshore flow in the upper 150m of the water column at water depth of 350m, 100m and 60m was between 0.1 ms^{-1} and 0.25 ms^{-1} in northward direction suggesting that the poleward Undercurrent (PUC, Mittelstaedt, 1983) off Mauritania is stronger in early boreal summer compared to the winter season. However, elevated intermittency of the current was also observed (Fig. 5.2.1.4).

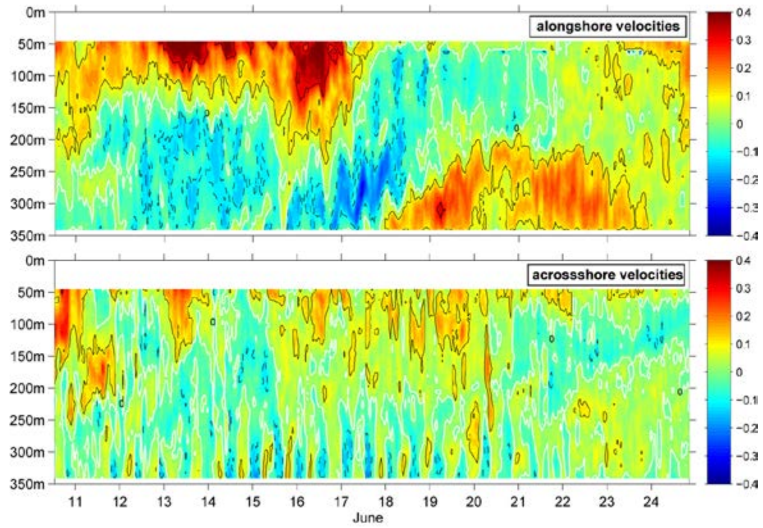

Fig 5.2.1.4 Along-shore and across-shore velocity at 350 m water depth at 18°20’ N from a Longranger ADCP. Elevated northward velocities were observed during the first week of deployment. Bottom intensified tidal currents are prominent in across-shore velocity.

5.2.2 CTD measurements

(Marcus Dengler, Alice Pietri, Sören Thomsen)

CTD/O_2 measurements

A total of 73 CTD profiles were collected during M107 (see stationlist 7). During the whole cruise the GEOMAR SBE#7 with a Seabird SBE 9 CTD rosette system was used. The CTD system was equipped with one Digiquartz pressure sensor (s/n 1162) and double sensor packages (temperature 1 = s/n 5806, temperature 2 = s/n 5807, conductivity 1 = s/n 3959, conductivity 2 = s/n 4164, oxygen 1 (sbe 43) = s/n 1812, oxygen 2 (sbe 43) = s/n 1818). The oxygen sensors were borrowed from FS Meteor as all GEOMAR oxygen sensors were destroyed during the container transport to the M104 cruise, during which all CTD equipment was shipped.

Data acquisition was done using Seabird Seasave software version V7.22.1. The CTD was mounted on a rosette frame with a 24-bottle rosette sampling system with 10-liter bottles. Except during a few optode calibration casts where 3 to 8 bottles were removed, all 24 bottles were mounted to the frame. All sensors worked without problems during the whole cruise. For the final data we decided to use the secondary set of sensors for all CTD profiles.

The GEOMAR Guildline Autosal salinometer #5 (s/n 56121) was used for CTD conductivity cell calibration (operated by A. Pietri). Calibration during operation was done in two ways: IAPSO Standard Seawater (P150, K15=0.99978) was measured at the beginning of the salinometer use. In addition, a so-called “substandard” (essentially a large volume of water with constant but unknown salinity), obtained from deep bottles from the CTD casts was used to track the stability of the system. The salinometer worked very well throughout the cruise. Altogether, 98 samples were analyzed and used to calibrate the two conductivity cells of the CTD. The conductivity calibration of the downcast data was performed using a linear fit with respect to conductivity (c), temperature (t) and pressure (p) using C_corrected = C_observed - 0.033761 - 5.5369e-07*p - 0.001217*t + 0.012181*c. An uncertainty of salinity of 0.0017 PSU was found for the downcast. We chose the downcast as final dataset as: 1) Sensor hysteresis starts from a well-defined point, and 2) the incoming flow is not perturbed by turbulence generated by the CTD-rosette. For the oxygen calibration, 348 water samples were taken from the CTD rosette. These samples were titrated using standard Winkler technique (operated by Sven Trinkler and the Mauritanian observer Mamadou Ba). The oxygen calibration of the downcast data was then done using a linear fit with respect to oxygen concentration (o), temperature, and pressure resulting in: O_corrected = O_observed + 3.5846 - 0.0003934*p - 0.14855*t + 0.074867*o. Here an uncertainty of 1.5 µMol/kg was determined.

Preliminary results: A research focus of the cruise was to investigate variability of oxygen concentrations in the water column in response to variability of ocean circulation and biogeochemical processes. During the first half of the cruise, very low oxygen concentrations were found in the upper thermocline waters of the continental slope and shelf region (Fig. 5.2.2.1). A likely explanation of the low oxygen concentration is the sluggish boundary circulation (e.g. Dengler et al., 2008) and the enhanced oxygen consumption during the boreal winter upwelling season.

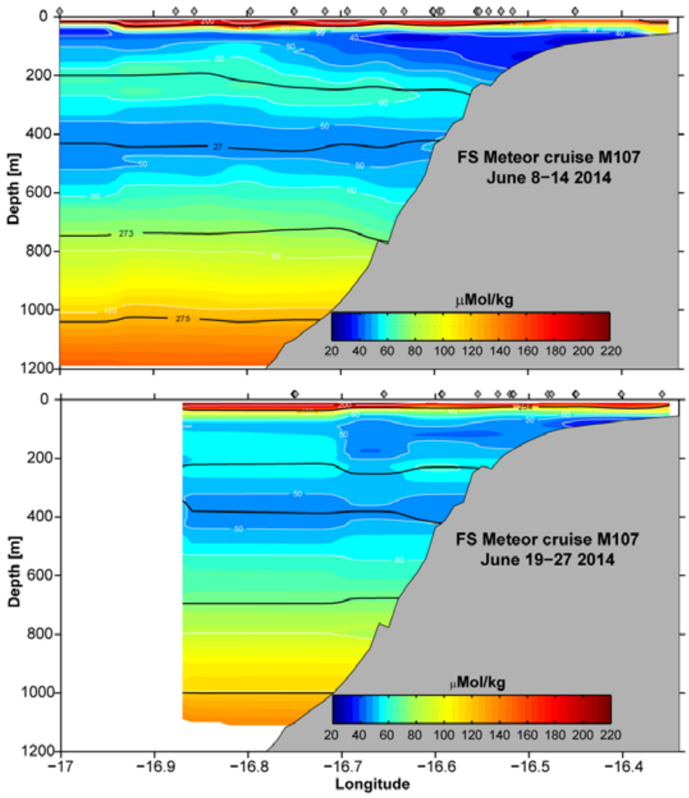

Fig 5.2.2.1 Oxygen concentrations (color contours) and density (black lines) along the 18°20' N transect from June 8 to 14 (upper panel) and June 19 to 24 (lower panel). O_2 concentrations in the upper oxygen minimum zone (50-150m) at the continental slope and shelf were much lower during the first period than during the second period. It is assumed that the PUC replaced the low-oxygen waters with more ventilated waters from the south.

5.2.3 Vessel mounted current measurements

(Marcus Dengler, Alice Pietri, Sören Thomsen)

Current measurements of the upper ocean have been performed continuously throughout the cruise using RV METEOR's two RDI Ocean Surveyor (OS) instruments (38 kHz and 75 kHz). Both Ocean surveyor instruments worked well throughout the cruise. The OS75 was configured to sample data in the narrow-band (NB) mode during transect from Brazil 01.06.2014 to Mauritania 08.06.2014 (number of bins: 100, bin length: 8 m, blanking distance: 4 m). An example of the meridional currents is shown in Figure 5.2.3.1. Thereafter, the configuration was switched between theNB and broad-band (BB) mode depending on the water depth (number of bins: 100, bin length: 4 m, blanking distance: 2 m). The BB mode was used on the continental slope and shelf to better resolve non-linear internal waves. The range of the OS75 was typically about 700 m in BB mode and 400 m NB mode. Also the OS38 was configured to sample in NB mode (number of bins: 55, bin length: 32 m, blanking distance: 16 m) during transect from Brazil to Mauritania. As for OS38, the configuration was switched between NB and BB mode depending on the water depth (BB mode: number of bins: 80, bin length: 16 m, blanking distance: 8 m). The range of the OS38 was about 1200 m to 1500 m in the NB mode and about 900 m in the BB mode, depending on sea state and ship's speed.

Post-processing of the OS75 and OS38 data was carried out separately for NB and BB mode. For the OS75, a mean misalignment angle of -1.0747°/-0.9271° with a standard deviation of 0.61°/1.03° for NB/BB mode resulted from calibration, respectively. An amplitude factor of 1.006/1.005 with a standard deviation of 0.012/0.017 for NB/BB, respectively, was found for the OS75. For the OS38 a mean misalignment angle of -0.1731°/-0.2312° with a standard deviation of 0.69°/0.87° for NB/BB mode resulted from calibration respectively. An amplitude factor of 1.004/1.0031 with a standard deviation of 0.012/0.013 for NB/BB, respectively, was found for the OS38.

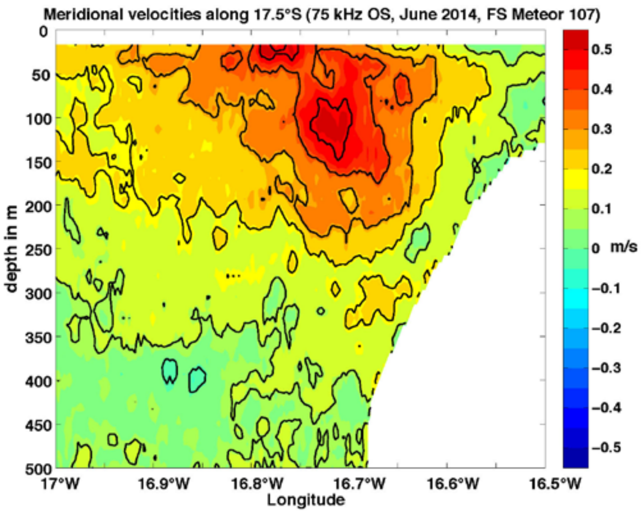

Fig. 5.2.3.1 Transect of meridional velocity along 18°20'N measured by the OS75 at 8. June 2014. The PUC is observed within the upper 300 m showing a velocity maximum exceeding 0.5 ms^{-1} in 100 m depth.

5.2.4 Turbulence measurements using the microstructure CTD

(M. Dengler, Lee Bryant)

A microstructure measurement program was carried out aiming at quantifying diapycnal fluxes of oxygen and nutrients along the Mauritanian continental slope and on the shelf. The measurement program consisted of autonomous microstructure sampling by two gliders equipped with a MicroRider (see section 5.2.1) and of shipboard microstructure sampling using a profiling system manufactured by Sea & Sun Technology.

Glider-MicroRider package: As mentioned in section 5.2.1 the MicroRider were attached to the top of gliders ifm2 and ifm3. Each MicroRider was equipped with two microstructure shear sensors and two fast-responding temperature sensors (FP07). The MicroRider worked well throughout the two missions and the packages returned with a full data microstructure data set. Details of the MicroRider configuration are given in table 5.2.4.1.

Table 5.2.4.1 Deployment schedule and configuration of MicroRider/Glider packages.

Glider mission / MR	Date (UTC)	Channel and shear sensors, sensitivity and orientation	Channel and Temp. sensors
ifm02, Depl22 MR sn 38	19 June – 30 June 2015	S1: M1103, S_0=0.0868, w' (vert.) S2: M1104, S_0=0.0937, y'(horiz.)	T1: T501 T2: T606
Ifm10-1 MR sn 57	09 June – 27 June 2015	S1: M1019, S_0=0.0958, y' (horiz.) S2: M1020, S_0=0.0977, w'(vert.)	T1: T724 T2: T856

Microstructure Profiling: For the ship-based microstructure measurements a MSS90-D profiler (S/N 32), a winch and a data interface was used. The loosely-tethered profiler was optimized to sink at a rate of 0.55 ms^{-1}. In total, 278 profiles were collected during 38 microstructure stations. The profilers were equipped with three shear sensors, a fast-response temperature sensor, and an acceleration sensor, two tilt sensors and conductivity, temperature, depth sensors sampling with a lower response time. All sensors worked well and no sensor needed to be replaced. Before MSS station 23 (profile 155) on 21 June the cable connecting the winch with the profiler was reconnected due to a water leakage. 30m of cable were removed at the profiler end. During the whole cruise shear sensor sn 123 was attached to channel S1, shear senor sn 029 was attached to S2 and shear sensor sn 052 was attached to S3.

5.3.1 Water column nutrient geochemistry

(Marcus Dengler, Bettina Domeyer, Stefan Sommer)

To date the fluxes of solutes from the sediment to the stratified water column and their contribution to the total solute budget of the oxygen minimum zone are poorly quantified. In addition transport across the shelf and slope is also hardly determined. Coastal upwelling is considered as major transport mechanism to supply nutrients to the mixed surface layer where they contribute to sustain high primary productivity. Near continental boundaries turbulent mixing provides another mechanism that transports nutrients and other solutes to the sea surface and entrain them into the surface mixed layer. In fact several studies suggest that a significant proportion of the biological production in the surface water is driven by turbulent fluxes of nutrients (e.g. Hales et al. 2009, Rippeth et al. 2009, Schafstall et al. 2010). The combination of microstructure data (see section 5.2.4) in combination with nutrient profiles allows to calculate diapycnal fluxes of nutrients and to relate them to benthic fluxes. For the upwelling region of Mauritania an average nitrate flux in the region of the continental slope and the shelves of 12×10^{-2} µmol m^{-2} s^{-1} was calculated (Schafstall et al. 2010).

During the cruise NO_2^-, NO_3^-, phosphate (PO_4^{3-}) and silicate (SiO_2) were measured on-board using a QuAAtro autoanalyzer (Seal Analytical) with a precision of ±0.1 µmol L^{-1}, ±0.1 µmol L^{-1}, ±0.2 µmol L^{-1}, and ±0.24 µmol L^{-1} respectively. A total of 73 CTD/water sampling rosette casts were sampled for nutrients with major focus on the 18°20'N transect and to a minor extent on the 19°50' N transect. For the station data of the different CTD/water sampling rosette casts used for nutrient analyses please see chapter 7 Stationlist.

5.3.2 Water column dissolved (DOM) and particulate (POM) organic matter

(Ruth Flerus, Hannes Wagner)

Water column dissolved organic matter (DOM)

Water column DOM was sampled to determine fluxes of dissolved organic carbon (DOC), dissolved organic nitrogen (DON) and dissolved organic phosphorous (DOP) within surface waters and the underlying shallow OMZ. For this purpose the water column was sampled with a high resolution from the surface to about 200m water depth using a CTD water sampling rosette. To investigate the role of both, biology as well as physics, on DOM fluxes, DOM sampling was coupled to microstructure measurements (see section 5.2.4), which were performed immediately before or following the sampled CTD casts.

CTD sampling

Samples for DOM analyses were collected from most of the CTD casts performed during M107 cruise. Sampling was performed in depth intervals of 5 - 10m from the surface to the shallow oxygen minimum followed by depth intervals of 20 – 50m from the shallow oxygen minimum to 200m depth. Exact positions of sampling stations and sampled depths are given in Table A4 (Appendix). The sampled seawater was filled from the CTD rosette water sampler into acid cleaned (hydrochloric acid, suprapur, Merck) HDPE bottles. On board these samples were prepared to be stored until analysis of DOC, DON, DOP, bacteria, phytoplankton and amino Acids (AA) in the home lab. Procedures of on board processing are described below. In addition, DOM and transparent exopolymer particles (TEP) were sampled at 3 selected stations, with a much lower depth resolution but down to water depths of 1000m (including the deep OMZ around 400m depth). Exact positions of sampling stations and depths are given as well in chapter 7 Stationlist. One CTD cast (performed independently from the microstructure measurements) was sampled for more detailed DOM characterization. In addition to the standard parameters (DOC, DON, bacteria, phytoplankton and AA) DOM was extracted via solid phase extraction (SPE). The extract fraction of DOM will be analyzed in the home lab.

Underway measurements using Fish during the transatlantic transit

During the transit across the Atlantic from Fortaleza to Mauritania water samples from surface waters were obtained using a towed Fish (see section 5.3.4). The Fish is a torpedo like looking steel instrument, which allows taking water samples from the sea surface. Samples were taken parallel to trace metal sampling performed by Christian Schlosser (see section 5.3.4) to enlarge the spectrum of analytical parameters during the transit. Samples were taken for home lab analyses of DOC, DON, bacteria and AA. SPE extractions were performed as well.

Sample processing on board

DOC/DON: 20mL of seawater was filtered through pre-combusted GF/F filters into pre-combusted 20mL glass ampoules. 85µL of phosphoric acid (85%, Sigma) were added to preserve the samples. The ampoules were sealed with a burner and stored at 4°C until analysis in the home lab.

DOP: 50mL of seawater was filtered through pre-combusted GF/F filters into acid cleaned (hydrochloric acid, suprapur, Merck) 50mL falcon tubes. 50µL of concentrated hydrochloric acid (p.a., Applichem) were added to fix the samples. Samples were stored frozen at -20°C until analysis in the home lab.

Bacteria/Phytoplankton: 2 x 4.0 mL of unfiltered seawater was filled into 4.5 mL PP sterile cryovials (Diagonal). Samples for bacterial cellcounts were fixed with 200µL, samples for phytoplankton analyses with 100µL of glutardialdehyde (25% solution, Applichem). Samples were stored frozen at -20°C until analysis in the home lab.

Amino acids: 3.5mL of seawater was filtered through pre-combusted GF/F filters into 4mL pre-combusted glass vials. Seals of the glass vials were acid cleaned with hydrochloric acid (suprapure, Merck). Samples were stored frozen at -20°C until analysis in the home lab.

TEP: 20mL of formaldehyde solution (35-38%, Walter CMP) were added to 980mL of unfiltered seawater. Samples were stored in acid washed PP bottles at 4°C until filtration and analysis in the home lab.

DOM extraction: Each 1L of GF/F (pre-combusted filters) filtered seawater was vacuum extracted through a 1g PPL SPE cartridge (Bond Elut, Agilent). Before each cartridge was washed with 1 cartridge volume of methanol (gradient grade, Merck) and activated with 1 cartridge volume of acidified (pH 2, HCL, p.a., Applichem) ultrapure water. Extraction speed was adjusted with vacuum to about 3mL per minute. The extracted DOM was rinsed with 1 cartridge volume acidified water and eluted from the cartridge with 5mL of methanol. The extracts were stored in pre-combusted glass ampoules at -20°C until analyses.

Preliminary Results: Preliminary results are not available since all analyses will be done in the home lab

5.3.3 Particle flux measurements with drifting sediment traps

(Hannes Wagner, Ruth Flerus)

Surface tethered free drifting sediment traps were deployed to study the influence of oxygen deficient waters on vertical particle fluxes. The specific questions were:

- How high are the export fluxes of different compounds (e.g. POC/PON) and the attenuation of these fluxes with depth?
- How does the biogeochemical composition of sinking POM change with depth?

Trap design

The design of the traps and the drifting array basically followed Knauer et al. (1979), with up to 12 individual Particle Interceptor Traps (PITs) mounted on a polyvinylchloride (PVC) cross frame. The PITs were acrylic tubes with an inside diameter of 7 cm, an outside diameter of 7.6 cm and a height of 53 cm, leading to an aspect ratio of 7.5. A baffle system consisting of smaller acrylic tubes was attached to the top end of each PIT (Soutar et al. 1977). PVC crosses with PITs were attached to a free-floating line ("METEOR-rope", d=11mm), which was buoyed at the surface and weighed at the bottom. Two complete trap arrays were available. The surface buoy of the first array carried a GPS/Iridium device (XEOS Beacon, Model KILO, S/N 449) and a Flashlight (XEOS LED Flasher, Model XMF-1000, S/N 394). The surface buoy of the second array carried a GPS/Iridium device (Optimare GPS-Tracker, S/N 002) and a Flashlight (XEOS LED Flasher, Model XMF-1000, S/N 395).

Trap deployments

Two deployments were performed. The first trap array was deployed at 18°08.20'N 16°52,36'W (1500 m water depth) on 11 June 2014 (19:00 UTC). It consisted of 8 depths (100 m, 150 m, 200 m, 300 m, 400 m, 500 m, 550 m, 600 m) with 8 PITs per depth. The second array was deployed at 18°12.41'N 16°36.22'W (470 m water depth) on 15 June 2014 (12:30 UTC). It consisted of 4 depths (100 m, 125 m, 150 m, 200 m) with 8 PITs per depth.

The second array was recovered at 18°10.60'N 16°42.48'W on 19 June 2014 (21:30 UTC). The first array was unfortunately lost after an "update" was performed by the satellite transmission company (Iridium), which resulted in a shutdown of the position transmission.

Sample treatment

Prior to deployment, each PIT was filled with 1.5 L filtered surface seawater (0.2 µm pore size cartridge) collected from the ships underway seawater system, up to ¾ of its height. A brine solution was prepared by dissolving 50 g/L NaCl with filtered surface seawater. It was subsequently filtered through a 0.2 µm cartridge to remove excess particulates. 20 ml formalin was then added per 1 L of the solution to achieve a brine solution with 2% formalin. 0.5 L of this dense brine-formalin solution was then slowly pumped into each PIT with a peristaltic pump beneath the 1.5 L of filtered seawater establishing a density gradient. Only the lowest ¼ (0.5 L) were chosen and filled with this solution to not loose aspect ratio. PITs were covered with lids until immediately before deployment, to minimize contamination.

After recovery of the second trap array, the lids were immediately put on all PITs, again to minimize contamination. The density gradient, which became established during filling of the PITs was inspected visually and was found to be intact at the position of prior to deployment or maximum 2 cm above. The seawater was pumped out of each PIT with a peristaltic pump down to 2-3 cm above the density gradient. The remaining ~0.6 L was subsequently transferred to canisters, pooled from the different PITs per depth. 25 ml formalin was added to each canister. Samples from each depth were flushed over a 500 µm mesh. Zooplankton swimmers were removed from the mesh with forceps under a binocular microscope and the remaining particles, which stuck to the mesh, were transferred back to the sample. Samples were subsequently split into aliquots of different size. The aliquots were then filtered using different filters and stored frozen (-20 °C) for later analyses of POC, PON and total mass.

5.3.4 Trace metal distribution in the Mauritanian upwelling zone and underway measurements during the transatlantic transit

(Christian Schlosser)

Objectives

It is well known that iron (Fe) and other trace metals, such as zinc, cadmium, and others, can be (co)-limiting nutrients for phytoplankton (Boyd, et al., 2010; Coale et al., 2004; Tsuda et al., 2003). However, very little is known about the processes by which these trace metals are supplied to the ocean (aeolian dust, resuspension of continental shelf sediments and offshore transport processes) and what mechanisms govern scavenge/uptake, solubility, mineralization or remineralization of dissolved trace metals. By examining trace metal chemistry in the moderate oxygen minimum zone (OMZ) off Mauritania we try to complete the overview of the key processes controlling biogeochemistry and mobilization of trace metals in the water column.

Sampling and methods

During the 7 day transit from Fortaleza to the Mauritanian upwelling zone surface seawater samples were collected with a towed Fish. Using the Fish water from the sea surface was pumped into the trace metal laboratory container using a Teflon diaphragm pump and an acid-washed braided PVC tube. The Fish was positioned in about 3 to 4 m water depth. Samples were filtered in-line through a 0.8/0.2 µm cartridge filter (AcroPak1000™) into acid washed low-density polyethylene (LDPE) bottles. At 35 locations surface seawater samples were collected for trace metal analysis, nanomolar nutrient analysis, incubation experiments, CDOM/FDOM analysis, and 4 L extracts (Table A5, Appendix).

Along the depth transect at 18°20'N off Mauritania covering a depth range from 50 down to 1100 m seawater samples were obtained from the entire water column using a new GEOMAR trace metal clean CTD rosette (TM-CTD) equipped with 24 trace metal clean Go-Flo bottles, Table A6 (Appendix). The TM-CTD water sampling rosette was attached to a nonconductive plastic coated steel wire and was deployed at the aft of the ship by a winch provided by the RV METEOR. The TM-CTD was equipped with a Seabird temperature/conductivity/pressure sensor and an auto release unit. Prior to each deployment the TM-CTD was programmed to close the different bottles at specified depths.

After recovery the Go-Flo bottles were immediately carried to the trace metal clean lab container. There, unfiltered seawater samples for total dissolvable trace metal analysis were transferred in acid washed 125 ml LDPE sample bottles. Another set of unfiltered samples for iodite/iodate analysis was collected in opaque 100 ml high density bottles and stored at -20°C.

Filtered seawater samples were obtained by applying a slight N_2 overpressure (~0.5 bar) to the Go-Flo bottle to filter the seawater through a 0.8/0.2 µm Acropak 500 cartridge filter (Pall). These samples were collected in acid cleaned 125 mL LDPE bottles. Further samples (500 mL) were filtered through acid washed 0.02 µm filters (Millipore) in order to collect the soluble trace metal fraction. The 0.02 µm filtrate was dispensed in acid washed 60 mL LDPE bottles. All seawater samples were acidified by Optima grade HNO_3 (50 µl for 60 ml and 100 µl for 125 ml seawater sample). Filtration and acidification of the samples were conducted in a laminar flow bench, preventing contamination. The samples were stored in the dark and shipped to the GEOMAR, Kiel for further analysis. The trace metal content of soluble, dissolved, and total dissolvable seawater samples will be analyzed by off-line pre-concentration and isotope dilution inductively coupled plasma mass spectrometry (ID-ICP-MS, Element XR, Thermo), following the method described by Milne et al. (2010). Analyzed elements of the different size fractions will be Fe, Zn, Co, Cd, Cu, Ni, Pb, Mn, Al, Cr, Ti, U, Ba, and Mo.

5.3.5 Water column radiotracer geochemistry

(Patrick Reichert, Beat Gasser, Jan Scholten)

Radioisotopes are widely used as tracers for the study of biogeochemical cycling of elements between the bottom boundary layer and the water column. Major objective of this cruise was to study the pathways and transport efficiencies of nutrients and associated elements between the benthic and pelagic compartment. For the radiotracer work, the following objectives were specified:

1) Radium isotopes

Due to the conservative behavior of radium in seawater only diffusive and advective transport and radioactive decay determine its concentration and distribution in the water column. The isotopes ^{223}Ra (half-life: 11.4 days), ^{224}Ra (half-life: 3.66 days), ^{226}Ra (half-life: 1600 years) and ^{228}Ra (half-life: 5.75 years) can therefore be used to estimate the time scales of water mixing and to calculate elemental fluxes from shelf sediments into the bottom boundary layer. The measurement of radium isotopes and integrating the data into adequate models allows to quantify fluxes of solutes of sedimentary origin into the water column and to describe iso-and diapycnal dispersion of these solutes [Ku and Luo, 2008] in order to estimate their relative contribution to the total solute budget of the oxygen minimum zone.

2) Thorium-234, ^{234}Th

Thorium-234 shows high reactivity with particles, while it’s long lived parent ^{238}U has a conservative behavior and remains soluble in seawater. The “scavenging” of ^{234}Th onto particles produced in the euphotic zone and exported through sedimentation causes a separation between daughter and parent nuclide. The resulting disequilibrium between the two nuclides is used to calculate the flux of particulate organic carbon out of the productive ocean surface layer (see Rutgers van der Loeff et al., 2006, Buesseler et al., 2006 and references herein). This is an important parameter when calculating the organic carbon budget between the sediment and the water column.

During cruise M107, in-situ filtration pumps were deployed at seven main stations along the depth-transect at 18°20’N. These stations were located in 53m, 92m, 174m, 241m, 410m, 782m and 1100m water depths where all other sampling devices (e.g. BIGO (Biogeochemical Observatory)) were deployed. Two additional deployments were carried out in 500m and 1600m water depths. These two latter sites were chosen in order to compare the particle flux determined using drifting sediment traps with the fluxes calculated using the ^{234}Th method. For the precise position of the “In-situ pumps” deployments see chapter 7.

In order to sample the productive mixed surface layer the in-situ pumps were deployed at each station in 5m, 15m, 30m and 80m water depths. These water depths were chosen based on CTD data acquired before the in-situ pump deployments. For deep waters sampling, depths were 50m, 100m, 150m and 250m above the seafloor. Each in-situ filtration pump was equipped with two particle filters and two MnO_2 impregnated cartridges for sampling of dissolved ^{234}Th and radium. The first particle filter (Nitrex tissue) sampled the >70 µm particle size class believed to represent the settling particles, and the second filter (micro quartz filter of 1 µm nominal size) sampled the suspended particles. Dissolved radium and ^{234}Th were sampled by adsorption on MnO_2 impregnated cartridges (CUNO Micro Klean III acrylic). For measurements of Ra-226 we took 11 water samples from the CTD Rosette at the same water depths as the deployment depths of the in-situ filtration pumps. For sampling the bottom boundary layer, Mn-fibers were attached in different heights (0.25 to 2.6 m) to the benthic observatories BIGO I and BIGO II, see section 5.4.2. Additionally a mooring was carried out to sample the water column in 174m water depth. The mooring was installed for three days on the seafloor with thirteen Mn-fiber bags attached to it. The Mn-fibers were fixed in heights of 1.4m, 2.8m, 3.8m, 4.8m, 5.8m, 6.8m 8.8m, 10.8m, 12.8m 14.8m, 16.8m 18.8m and 20.8m above the seafloor. The objective of the mooring was to close the sampling gap in the water column between benthic landers and the in-situ pumps.

Furthermore, along the depth-transect at 18°20'N sediment samples from four locations were obtained using a Multicorer. The sediments were sliced in 1 to 3 cm sections and porewater was extracted from the sediment slices using a porewater press for later Ra-226 determination in the home lab. On-board the ship the Mn-cartridges were washed, partially dried and measured for the short-lived isotopes ^{223}Ra and ^{224}Ra using a radium delayed coincidence counter (RaDeCC system). For the measurement of the dissolved ^{234}Th, the MnO_2 cartridges were stored for the transport to the home lab. From the Nitrex tissue filters particles were rinsed off and the water was filtered onto micro quartz filters, which are analyzed in the home laboratory for their ^{234}Th beta activity and carbon content. The micro quartz filters from the in-situ filtration pumps were deep-frozen.

5.3.6 Water column microbiology – N_2 fixation and primary production

(Clara Martinez, Niels Schoeffelen)

Objectives:

Investigations of marine dinitrogen (N_2) fixation have historically focused on areas where nitrogen (N) limits primary production, such as in the oceanic gyres of the North Tropical Atlantic (NTAtl). Despite playing a crucial role in the marine N cycle, still relatively little is known about the distribution and the factors that control biological nitrogen fixation in the NTAtl. There is scarce knowledge about the biological processes or the microbial community existing in the most productive waters of the upwelling area off the Mauritanian coast. N_2 fixation measurements have never been done in this region because it receives ample amount of nutrients through upwelling. These high concentrations are usually assumed to inhibit N_2 fixation activity. However, recent findings have discovered significant N_2 fixation rates in similarly productive areas in coastal waters off Peru (Loescher et al., 2014), the California Bight (Hamersley et al., 2011; White et al., 2013) and, most interestingly, the Equatorial upwelling area in the Eastern basin of the Atlantic (Subramaniam et al, 2013). Therefore, the main goal of our research is to assess whether N_2 fixation takes place significantly in the nutrient-rich upwelling waters off Mauritania. More specifically, we aim to estimate N_2 fixation activity and primary production in relation to the variability of light, oxygen and the hydrographic environment in the upwelling area. Furthermore, we plan to identify the major contributors to N_2 fixation within the diazotrophic community.

Experimental approaches: Stable isotopes of Nitrogen (^{15}N) and Carbon (^{13}C) were used in incubation experiments to study N_2 fixation rates and primary production, respectively. During this cruise, a total of twenty-three N_2 fixation and primary production incubation experiments were performed in the southern sampling area (18°20'N) and five in the Northern sampling area (19°50'N). Some of the sampling locations were repeated at different times to investigate the effect of the variable hydrographic regime on the community's activity and composition. Water samples were collected from 2-4 different depths corresponding to surface, deep chlorophyll maximum, hypoxic waters and/or bottom waters to cover the range of light and oxygen concentrations throughout the water column (sampling sites are illustrated in Figure 5.3.6.1 and Figure 5.3.6.2).

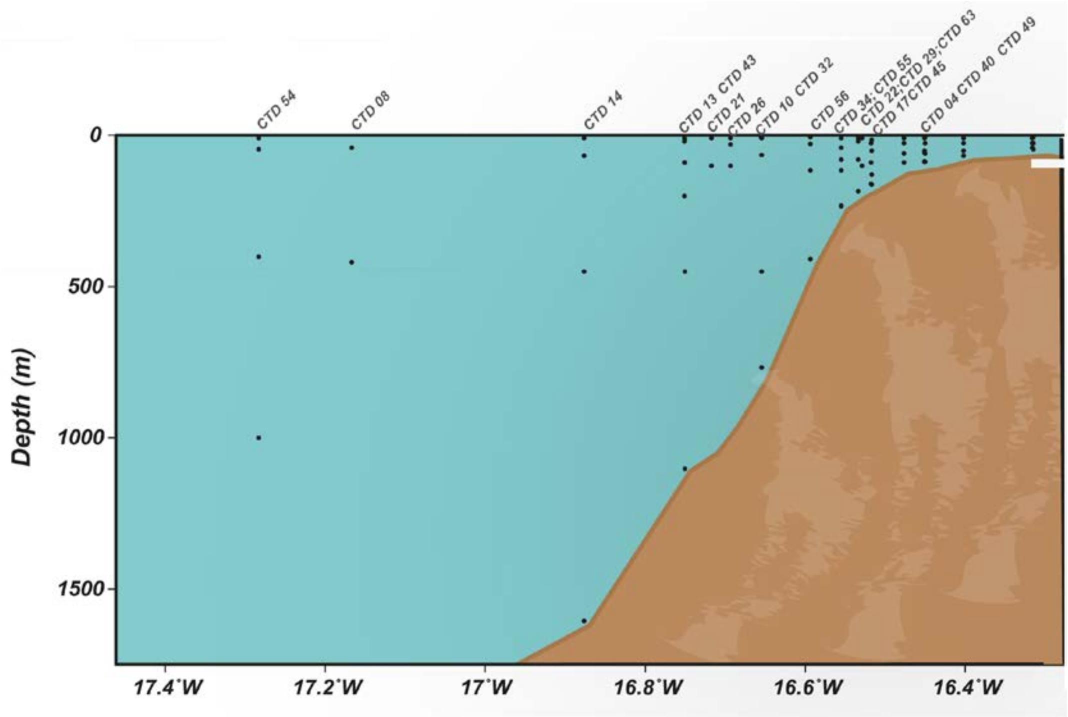

Fig. 5.3.6.1 Sampling scheme for the southern working area at 18°20'N. For the ocation of the different CTD casts see chapter 7 Stationlist.

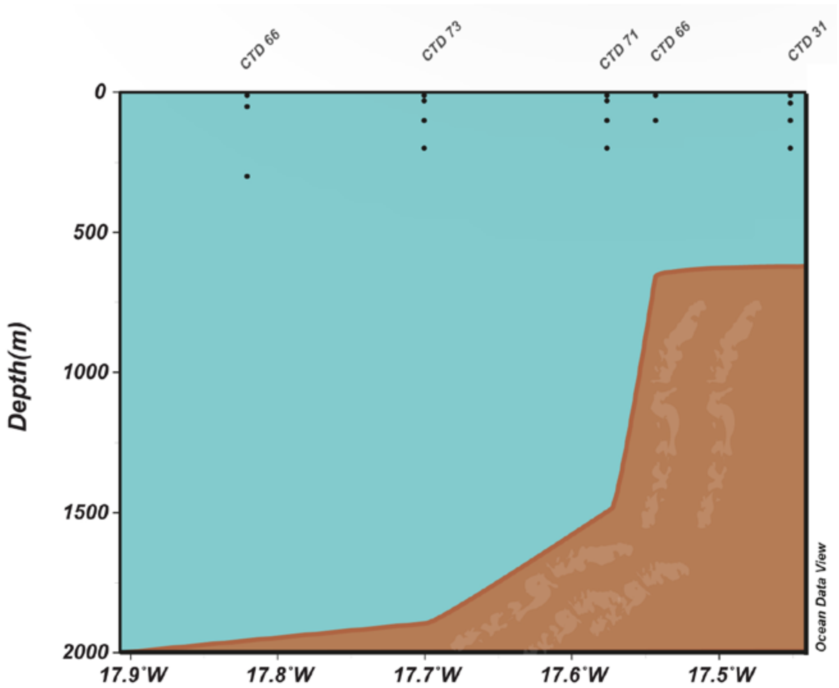

Fig. 5.3.6.2 Sampling scheme at the northern working area at 19°50'N. For the precise location of the different CTD casts see chapter 7 Stationlist.

Samples were obtained using Niskin bottles attached to a CTD rosette sampler. For each sampled depth, triplicate samples were collected in 2.7 L or 4.7 L polycarbonate Nalgene bottles, to which dissolved $^{15}N_2$ gas and $NaH^{13}CO_3$ tracers were added. Additionally, 4L from each sampled depth were collected and immediately filtered on 0.2µm polycarbonate filters which were stored at -80°C for later molecular analysis upon return to the home laboratory. The tracer-amended samples were incubated in "on-deck incubators" containing light filters that simulated the light conditions for the corresponding water depths. Seawater was continuously circulated during the incubation to maintain a constant temperature. For aphotic deep-water samples, bottles were incubated at 4°C in the dark. After 24 hrs of incubation, all samples were individually filtered through pre-combusted (4 h at 400°C) Whatman GF/F filters (25 mm diameter and 0.7µm pore size). The filters were dried in an oven at 50°C overnight and stored (dry and dark) for subsequent mass-spectrometric analysis at the home laboratory.

Subsamples were also collected for cell counts and fluorescence in situ hybridization (FISH): about 500ml of each incubated sample were preserved with paraformaldehyde solution (1-2% final concentration). From this subsample, 2ml were collected in Eppendorf vials or tubes for flow cytometry analysis (cell counts), ~ 400ml were filtered onto 47mm diameter polycarbonate filters (size-fractionated on 3 µm and 0.2 µm pore-size filters; FISH) and ~ 100ml were collected on separate filters for later nanoSIMS analysis (single-cell approaches).
Expected Results:

Bulk N_2 fixation and primary production rates will be measured by EA-IRMS mass spectrometry in the home laboratory to determine whether N_2 fixation occurs and if so, how significant is this process in the waters sampled. Based on these rate measurements, specific stations will be selected for further molecular analysis to estimate the diversity of the diazotrophic community. Using molecular biological techniques we will identify the relative abundances of the different phylotypes of diazotrophs using specific probes for the nifH gene, which encodes for the iron-subunit of the nitrogenase enzyme complex. Moreover, nifH gene expression analysis on these samples will reveal (potential) activity patterns of diazotrophs in relation to their abundance and bulk N_2 fixation rates. By combining our results with the hydrography and biogeochemistry of the water column we will be able to define the impact of these changing conditions on the microbial community's composition and activity and shed light on the factors that influence marine N_2 fixation in nutrient-rich waters.

5.3.7 Water column, virology

Sven C. Neulinger

Objectives

OMZs are oceanic features characterized by high production and low oxygen concentrations favoring anaerobic pathways in the nitrogen and sulfur metabolism driven by microbes (bacteria and archaea). The impact of viral infection of these microbes is important in terms of nutrient stoichiometry and biogeochemistry since it causes nutrient release through cell destruction. Moreover, viruses add to microbial genetic diversity by transmission of auxiliary metabolic genes (AMGs). Our goal is to study and evaluate the influence of viruses on the overall biogeochemical processes in the OMZ. Currently, it appears that no linkage exists between free viruses and putative microbial (bacterial as well as archaeal) hosts in the OMZ (Cassman et al. 2012). Consequently, the overarching goal of the present study is to test the hypothesis that microbial hosts of viruses prevailing in the OMZ are particle-bound rather than free. The specific objectives and corresponding scientific questions of our research are:

Q1: Identification of viral gene sequences in free and particle-bound microbial communities: What microbes are infected by which viruses?
Q2: Evaluation of the degree of connectivity between respective free and particle-bound virome and microbiome partitions: To what extent can free or particle-bound viruses be found in free or particle-bound microbes in the OMZ, respectively? What is the VMR (virus-microbe ratio) in each fraction?
Q3: Identification of AMGs in free and particle-bound viruses: Do viruses in the OMZ carry genes that can give infected microbes a metabolic advantage over non-infected ones? Does this include genes involved in nitrogen and sulfur cycling.
The synthesis of objectives Q1 Q3 will enable us to sustain or refute the above-mentioned hypothesis.

Sampling

Water samples (~20 L each) were taken from the oxic mixed surface layer as well as from the core of the shallow biology-driven OMZ at six stations along the 18°20'N-transect of this cruise. Surface samples serve as references in order to detect effects of oxygen concentration and/or particle export on the composition of viral and microbial communities. Viral and microbial contents of the water samples were separated into three partitions: (i) Particle-bound microbes and viruses, (ii) free-living microbes and (iii) suspended viral particles. Particles and aggregates such as marine snow with associated microbes and viruses were retrieved from a water sample by filtration through a 10 µm pore-size membrane filter. Free-living microbes were retained by consecutive filtration of the 10 µm flow-through of same water sample through a 0.22 µm pore-size membrane filter. The free viral fraction in the 0.22 µm flow-through was concentrated by chemical flocculation with Fe(III) (by addition of dissolved $FeCl_3$) followed by 0.8 µm pore-size filtration as established by John et al. (2011). Water samples for flow cytometry (10 ml each) were taken from the 10 µm flow-through and preserved in 4% formaldehyde (final concentration). All samples were snap-frozen in liquid nitrogen and stored at -80°C until transport to the lab by dry-shipper.

Further sample processing in the lab

Precipitated viruses will be subsequently released from the Fe(III) precipitate by ascorbate/EDTA treatment. Particle-bound microbes and viruses will be detached from aggregates by a combination of enzymatic (α glucosidase, β galactosidase and lipase), chemical (sodium pyrophosphate) and ultrasonic treatment (Böckelmann et al. 2003) and separated by 0.22 µm pore-size filtration. Detached viruses present in the flow-through will be concentrated by ultracentrifugation. DNA will be extracted from separated microbial and viral fractions using established protocols and directly subjected to MiSeq high-throughput sequencing at the Max Planck Institute for Evolutionary Biology (Plön, Germany). Subsequent analysis of sequencing data will involve quality-filtering, assembly of reads to contiguous sequences – so-called 'contigs' – and gene calling. Data processing will be largely automated by a custom bioinformatic pipeline (developed in-house by SCN at the Institute for General Microbiology) and facilitated with CAU's supercomputing infrastructure.

Meeting of research objectives

Q1: Taxonomic classification of microbial contigs will be conducted by a MEGABLAST query (Altschul et al. 1990, Zhang et al. 2000) against a database consisting of genome sequences of known bacteria and archaea. This will yield information on the identity of the bacterium or archaeon, which a contig is most likely derived from. A second query against collections of known viral genomes will identify stretches of viral sequences in the same data.
Q2: The approach described for objective Q1 will be employed to classify the free and particle-bound viromes. The connectivity between viromes and microbiomes can then be assessed as the fraction of identified free and particle-bound members of the viral community found in each microbiome partition. Moreover, a cross-over MEGABLAST search with viral sequences as query items and microbial sequences as subject items will provide additional information on the degree of community overlap. Flow cytometry will be applied to estimate the numbers of microbial cells and viral particles in the respective fractions, which will allow calculation of the VMR through direct counting.
Q3: Putative protein-coding gene sequences in viral contigs identified by gene calling will be annotated by searching against databases of known protein sequences. This will directly give the names and functions of known protein-coding genes contained in the viral sample fractions, including AMGs if present.

5.3.8 Measurements in the bottom boundary layer

(Mustafa Yuecel, Stefan Sommer, Bettina Domeyer)

As a part of the collaboration with National Oceanography Centre (NOC) Southampton within the Helmholtz Alliance ROBEX and in the framework of SFB 754 we deployed lab-on-chip (LOC) technology based on microfluidic nutrient measurement systems at various stations along the 18°20' transect. These sensors have been developed in NOC Southampton and University of Southampton, Ocean Technology and Engineering Group (see Beaton et al. 2012 for details) and were now tested for the first time in the field. The LOC sensors enable low sample and reagent consumption due to the precision-milled micro channels (<200um), mixers and optical detection cells on a PMMA chip. An integrated syringe pump and electronic control unit complements the chip, encased in an oil-filled pressure compensating housing for deployments. The LOC system used the Griess assay for nitrite (NO_2^-) measurement. The addition of an off-chip Cu-activated Cd column enables nitrate (NO_3^-) detection through the reduction of nitrate to nitrite and subsequent analysis on chip. Detection limit for NO_2^- and NO_3^- are about 20 nM (Beaton et al. 2012). In situ standard solution and blank measurements were performed regularly during the deployments to account for the drift of the sensor or response of the sensor to changing environmental conditions. In the deployments the sensor was set to start with two sets of calibrations (blank and two standards) and then the sensor repeated a sequence involving the measurement of blank-sample-standard solution and sample again. With this scheme a blank-corrected sample measurement can be obtained in 14 minutes. The system ran autonomously as battery-powered and stored the data in a memory card.

Major aims were (i) to demonstrate that LOC technology is suitable for in situ measurements in marine environments where it could strongly contribute to understand marine nitrogen cycling; (ii) to obtain time series of bottom water NO_3^- and NO_2^- at regions where strong variability in the oxygen availability were known. Investigations integrating the LOC into the CTD/RO and a Profiler lander were conducted at the 50 to 200 m depth range where low-oxygen waters impinges the Mauritanian margin, see Table A7 (Appendix).

Figure 5.3.8.1 shows the integration of the LOC device on CTD rosette and the Profiler. The benthic lander also included a voltammetric sediment profiler in all deployments. Except for the first profiler deployment, the lander also included two AANDERAA oxygen optodes and a CTD (RBR).

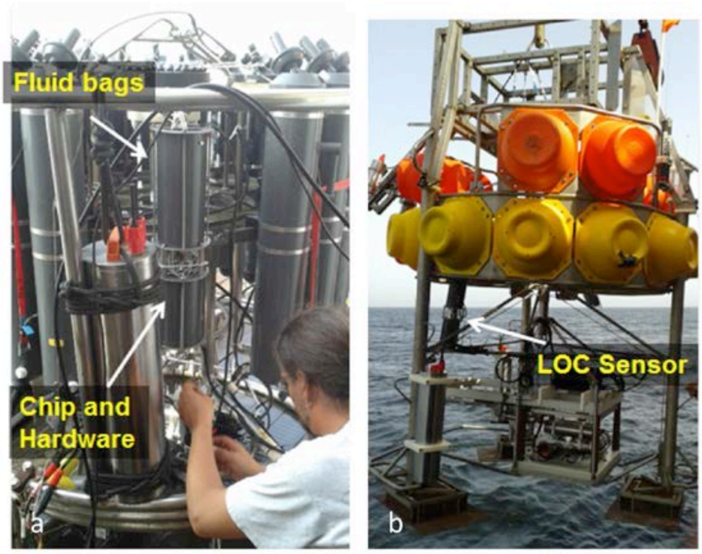

Fig. 5.3.8.1 Lab on chip nutrient measurement system attached to the CTD rosette (a) and the Profiler (b).

Preliminary Results

Figure 5.3.8.2 depicts the simultaneous in situ detection of nitrate and nitrate on the shallow shelf in 50 m water depth. The results showed that sub-micromolar nitrite levels can be precisely measured using the LOC. NO_2^- and to a lower extent NO_3^- were changing with time. This might be due to the poleward flowing undercurrent (see Fig. 5.2.3.1), which changes its distance to the coast resulting in different water masses at the Profiler position. The bottom water samples taken via the BIGO lander at this depth (as well as other locations) also revealed a similar magnitude of variability in NO_3^- and NO_2^- levels. Specifically, when the results of the bottom water measurements during BIGOII-4 are combined with the LOC measurements during Profiler #3, a 3-4 day cycle emerges where relatively nitrite enriched, nitrate depleted waters were replaced by waters higher on nitrate and lower in nitrite. In summary, the LOC deployments were a success and demonstrated the utility of these sensors to gather critical data from marine bottom boundary layers.

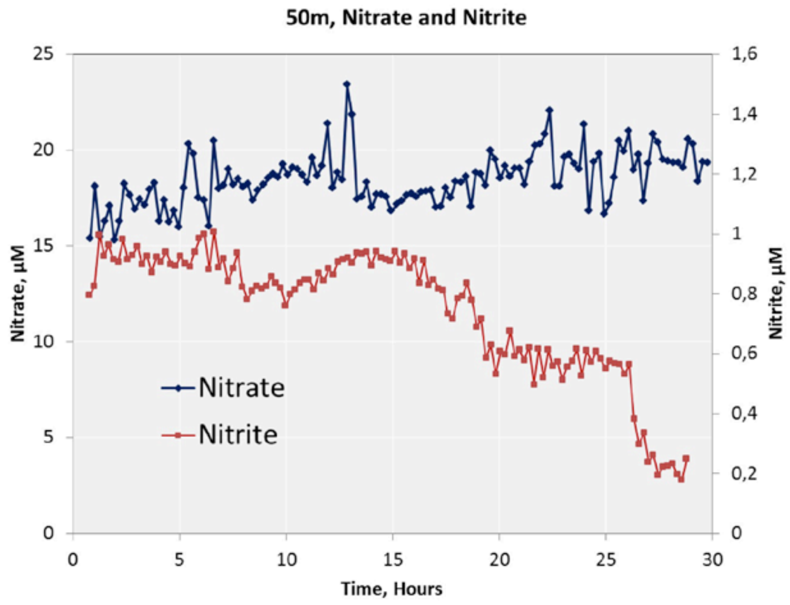

Fig. 5.3.8.2 Nitrate and nitrite time series recorded during Profiler deployment #3 (M107-687) at 50 m water depth three lander deployments using LOC technology.

5.4.1 Pore water geochemistry

(Andrew W. Dale, Bettina Domeyer, Ulrike Lomnitz, Verena Thoenissen, Sven Trinkler)

Objectives

The porewater composition of surface sediments was investigated at nine stations at the 18°20'N transect in order to characterize and quantify sediment diagenetic processes below the oxygen-deficient waters offshore Mauritania. One aim of this cruise was to further our understanding of the benthic-pelagic coupling in oxygen deficient regions of the ocean by examining key geochemical species whose chemical behavior and distribution are altered via changes in redox potential. Specific emphasis was placed on the biogeochemical cycling of redox sensitive elements such as N, P and Fe, which are preferentially released from sediments under oxygen deficient bottom waters. The magnitude of this recycling flux, the relative importance of key control parameters, and the coupling to the carbon cycle are still poorly understood. In order to overcome this lack of knowledge, we performed geochemical analyses of pore water from surface sediments that were retrieved by multicorer and lander deployments (see section 5.4.2).

Methods

Sediment cores were retrieved using the multiple-corer (MUC) in addition to smaller push cores recovered with the BIGO landers. An overview of the sampling stations where porewater was analyzed is given in Table A8 (Appendix). After retrieval, all cores were transferred to a cooling lab (12°C, mean bottom water temperature along the transect) and processed within 1-2 hours. Supernatant bottom water of the multicorer-cores was sampled and filtered for subsequent analyses. In general, more than one MUC or BIGO sediment core was taken at the same site, but not necessarily on the same day. For all measurements and sub-sampling for redox-sensitive parameters (e.g. Fe, nutrients) from the MUC cores, the porewater was either sampled using rhizones or extracted from the core that was first sectioned in an argon filled glove bag. The sampling depth resolution increased from 0.5 cm at the surface to 2 cm at depth. Rhizons were mainly applied to the sandier sediments on the upper slope and shelf (water depth <400 m) where core sectioning is problematic. The first 0.5 ml of pore water extruded through the Rhizones was discarded. Porewater extraction using this method required up 30 minutes, yielding around 10 ml of porewater at each depth interval. Sediment samples from the MUC cores sectioned in the glove bag were spun in a cooled centrifuge at 4000 G for 20 min to separate the porewater from the particulates. Subsequently, the porewater samples were filtered (0.2 nm cellulose-acetate filters) under an argon atmosphere. All BIGO cores were sectioned under ambient atmosphere and porewater extracted using pressure filtration (max. 5 bar) and then filtered (0.2 µm cellulose acetate filters). Sediment samples were also taken for the calculation of sediment density and water content as well as solid phase constituents in the onshore laboratory.

At 7 stations along the transect, cores from the MUC (10 cm internal diameter) were taken for manipulation experiments to determine bioirrigation rates. The procedure involves adding a large excess of a dissolved conservative tracer, in this case 5 g NaBr dissolved in seawater, to the water overlying the sediment and allowing the core to incubate for a known period of time (5 to 7 days). Posterior analytical determination of the depth distribution of Br– allows the rate of irrigation to be approximated by modeling the transient infiltration of Br– into the sediment using a numerical model (Dale et al., 2013). Following delivery to the onboard cool room, the sediment cores were allowed to settle for a period of 24 h whilst stirring (60 rpm) the overlying water at approximately 15 cm above the sediment surface in darkness. Observed trajectories of small amounts of suspended particulate material at the bottom of the overlying water showed that this rate of stirring was sufficient to ventilate the surface of the sediment. It was not possible to control the dissolved O_2 concentration of the overlying water at all stations, and the cores were left partially open to the atmosphere using plastic stoppers except at the shallowest site where the O_2 concentration was monitored using an O_2-sensitive spot (Presens). In this core, sealed and stirred, the O_2 concentration was maintained to within 10 µM of the in situ concentration by bubbling the core with Argon or air. Two grams of glass beads (50-70 µm in diameter) were also added to the cores at the same time as the NaBr to make an initial estimate of bioturbation rates following the procedure described by Berg et al. (2001). At the end of the incubation period, the porewater was extracted using the gas press or rhizones for analysis of Br- and the sediments were sectioned and bagged for counting the distribution of glass beads in the home laboratory using a microscope. The presence of macrofauna in the sediment was noted but not measured quantitatively.

A total of 269 porewater samples were recovered and analyzed (Table A8, Appendix). Porewater analyses of the following parameters were carried out onboard: ferrous iron (Fe^{2+}), nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+), phosphate (PO_4^{3-}), silicate (H_4SiO_4), total alkalinity (TA) and hydrogen sulfide (H_2S). For H_2S analysis, an aliquot of pore water was diluted with appropriate amounts of oxygen-free artificial seawater and the sulfide was fixed by immediate addition of zinc acetate gelatine solution immediately after pore-water recovery. After dilution, the sulfide concentration in the sample was < 50 µmol/l. All the above listed species with the exception of TA were measured photometrically using standard methods described by Grasshoff et al. (2009). NO_3^- and NO_2^- were determined on a Quaatro Autoanalyzer (Seal Analytic) with a detection limit of 30 and 5 nM, respectively, and a precision of 0.8 and 1.8 % (respectively). NH_4^+, PO_4^{3-}, H_4SiO_4 and H_2S nitrate were determined on a Hitachi U-2001 spectrophotometer with detection limits of 2, 5, 1 and 1 µM (respectively) and precisions of 5, 1, 5 and 3 µM (respectively). For the analysis of Fe^{2+} concentrations, sub-samples of 1 ml were taken within the glove bag and immediately complexed with 20 µl of Ferrozin. The precision of this assay was <2 %. Samples for TA were analyzed by titration of 0.5-1 ml pore water according to Ivanenkov and Lyakhin (1978). Titration was ended when a stable pink colour appeared. During titration, the sample was degassed by continuously bubbling nitrogen to remove any generated CO_2 and H_2S. The acid was standardized using an IAPSO seawater solution. The detection limit and precision of the method is 0.05 meq L^{-1}.

Untreated samples were also frozen for onshore analysis of chloride, bromide, and sulphate by ion-chromatography. Acidified sub-samples (35µl suprapure HCl + 3 ml sample) were prepared for analyses of major ions (K, Li, B, Mg, Ca, Sr, Mn, Br, and I) and trace elements by inductively coupled plasma atomic emission spectroscopy (ICP-AES). DIC, δ18O, δ13C of CO_2 and stable N isotopes (^{15}N, ^{14}N) will be determined on selected sub-samples in the shore-based laboratories.

Results (onboard)

A selection of the porewater profiles from sediment cores retrieved during MUC deployments are shown in Fig. 5.4.1.1. Overall, the data resemble the trends observed at the same stations during cruise MSM17 in 2011 onboard RV Maria S. Merian 17 (Dale et al., 2013). NH_4^+ porewater concentrations displayed a steady down-core increase at all sites, yet never exceeded 150 µM NO_3^- was consumed within a few cm below the sediment surface at all stations. H_2S accumulated to 100 µM at 53 m but was below detection limit at all other deeper stations. TA varied little from the bottom water concentrations. Fe^{2+} and PO_4^{3-} tended to be more abundant at the deeper stations, which have a higher mud content that on the shelf. The sediments on the shelf were sandy in nature with a porosity of around 0.6 (Dale et al., 2013). Even though the benthic respiration rate was highest at this station, there is no clear build up of porewater NH_4^+ or alkalinity that would suggest high rates of organic matter degradation. Analysis of the Br- data in the irrigation incubation experiments will help to show whether the pumping of porewater through animal burrows is enhanced on the shelf, thereby preventing accumulation of NH_4^+ and alkalinity. These data will be further analysed using a numerical reaction-transport model to quantify the relative importance of irrigation, diffusion and advection to benthic solute exchange at 18° N on the Mauritania margin (e.g. Bohlen et al., 2011).

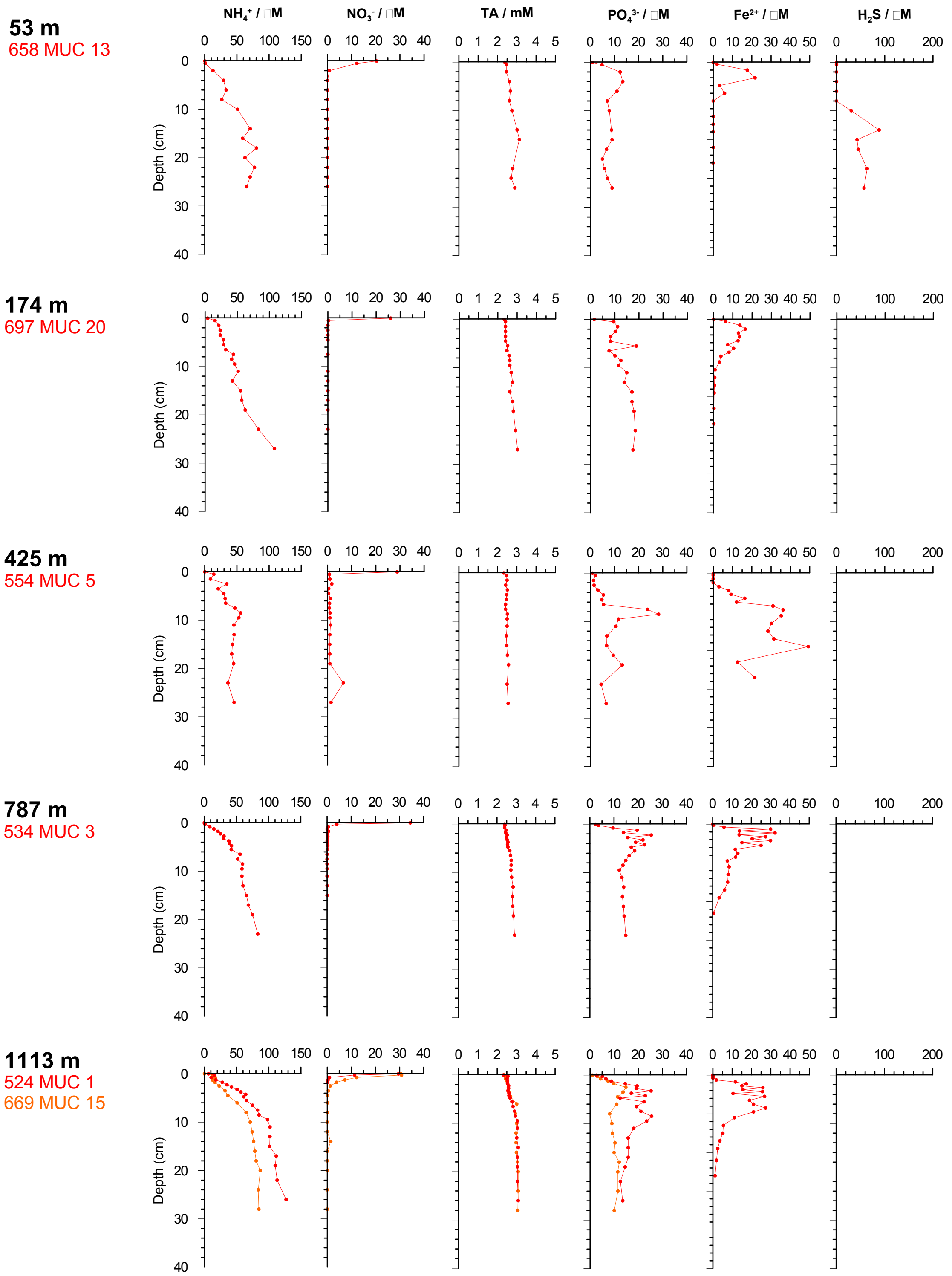

Fig. 5.4.1.1 Measured (symbols) concentration profiles of dissolved ammonium, nitrate, total alkalinity, dissolved phosphate, ferrous iron and hydrogen sulfide in sediments sampled by the multi-corer at selected water depths.

5.4.2 In situ benthic fluxes using the Biogeochemical Observatories BIGO I and BIGO II

Stefan Sommer, Sonja Kriwanek, Matthias Türk, David Clemens, Andrew Dale, Bettina Domeyer, Ulrike Lomnitz, Verena Thoenissen

The major task was to determine in situ fluxes of nitrogen species (N_2, NO_3^-, NO_2^-, NH_4^+) as well as P and Fe across the sediment water interface under conditions of different bottom water O_2, NO_3, NO_2^- concentrations and C_{org} content of the surface sediments. Total fluxes of the above mentioned parameters were measured in benthic chambers using the Biogeochemical Observatory (BIGO). Two structurally similar BIGOs (BIGO I and BIGO II) were deployed as described in detail by Sommer et al. (2009). In brief, each BIGO contained two circular flux chambers (internal diameter 28.8 cm, area 651.4 cm^2). A TV-guided launching system allowed smooth placement of the observatories at selected sites on the sea floor. Four hours after the observatories were placed on the sea floor the chambers were slowly driven into the sediment (~ 30 cm h^{-1}). During this initial time period where the bottom of the chambers was not closed by the sediment, the water inside the flux chamber was periodically replaced with ambient bottom water. The water body inside the chamber was replaced once more with ambient bottom water after the chamber has been driven into the sediment to flush out solutes that might have been released from the sediment during chamber insertion. To trace nitrogen fluxes (NO_3^-, NO_2^-, NH_4^+), iron, phosphorous and silicate release as well as total alkalinity 8 sequential water samples were removed with a glass syringe (volume of each syringe ~ 47 ml) by means of glass syringe water samplers. The syringes were connected to the chamber using 1 m long Vygon tubes with a dead volume of 5.2 ml. Prior to deployment these tubes were filled with distilled water. Another 4 water samples were taken from inside the benthic chamber using a peristaltic pump, which slowly filled glass tubes. These samples were used for the gas analyses of N_2, Ar, pCO_2 and dissolved inorganic carbon (DIC). To monitor the ambient bottom water an additional syringe water sampler was employed and another series of four glass tubes were used. The positions of the sampling ports were about 30 – 40 cm above the sediment water interface. O_2 was measured inside the chambers and in the ambient seawater using optodes (Aandera) that were calibrated before each lander deployment.

Deployments of BIGO-I and BIGO-II were conducted (see. Fig. 3.2, chapter 7 Stationlist) at the main sites at the 18°20’ N working area in water depths of 47, 91, 171, 236, 412, 787 and 1095 m. These stations were also investigated during the RV Maria S. Merian cruise MSM 17-1 during upwelling conditions (Dale et al. 2014). To increase spatial resolution additional BIGO deployments were conducted at 67 and 130 m water depths (BIGO-II-5 and BIGO-I-4, see chapter 7). Although not finally corrected, preliminary fluxes show that specifically the shelf and upper slope sediments were active sites with total oxygen uptake rates (TOU) of up to 16 mmol m^{-2} d^{-1} (Figure 5.4.2.1).

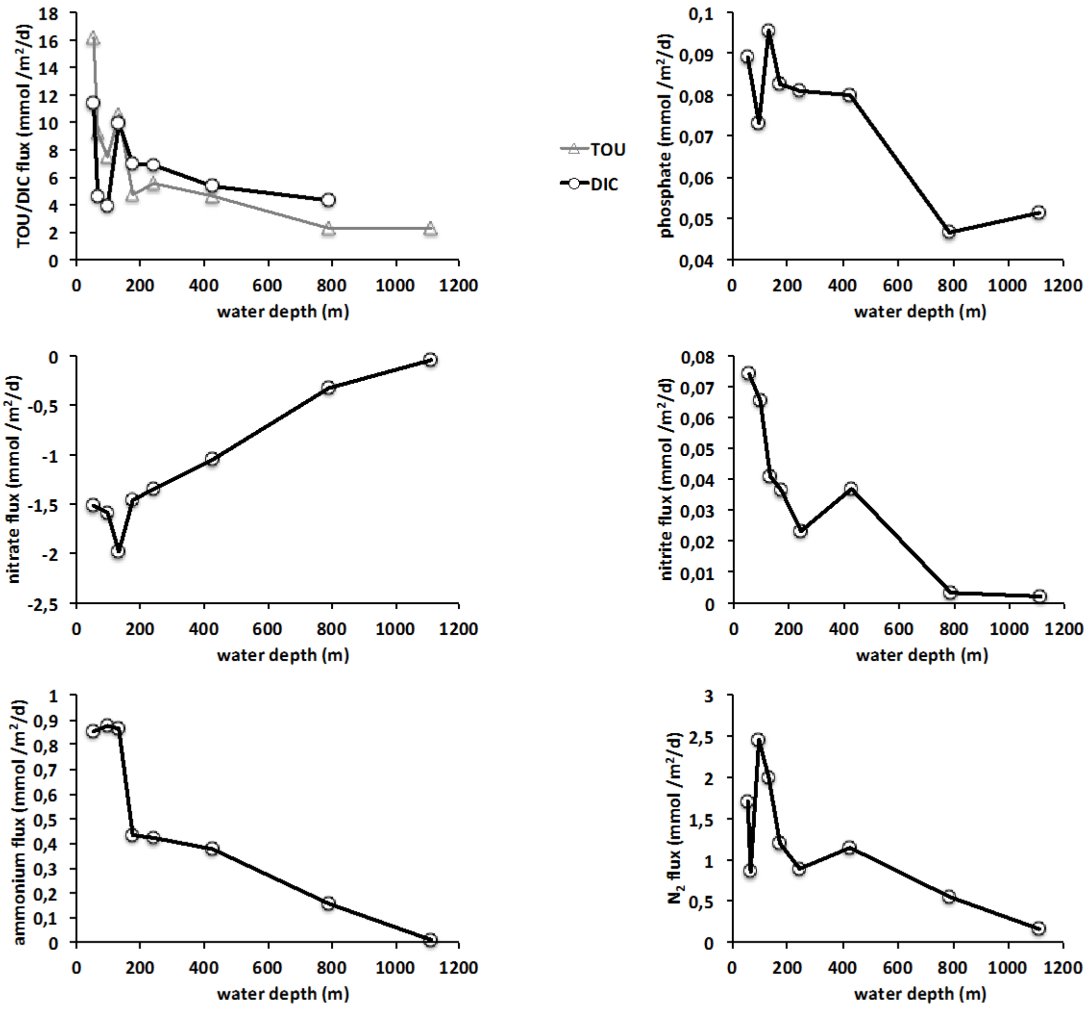

Fig. 5.4.2.1 In situ fluxes of total oxygen uptake (TOU), DIC flux, NO_3^-, NO_2^-, NH_4^+, and TPO_4 measured using the benthic observatories BIGO I and BIGO II along the depth transect at 18°20' N off Mauritania. Positive values denote a flux from the sediment to the water column and vice versa. Note these fluxes are preliminary and not finally corrected.

5.4.3 Microbiology of benthic N_2 fixation and associated processes

Jessica Gier, Tina Treude

Objectives

The aim of this work is the quantification and identification of nitrogen fixation and responsible organisms in surface sediments along the depth transect at 18°20'N inside and below the Mauritanian oxygen minimum zone, as well as to identify coupled metabolic processes, such as bacterial sulfate and iron reduction. One overarching goal is to incorporate nitrogen fixation rates into benthic nitrogen budgets gained from benthic lander flux measurements (see section 5.4.2) to better constrain the function of sediments to act as a source, sink, or recycling site for reactive nitrogen. Two additional experiments were conducted to investigate the inhibition of nitrogen fixation in the presence of different ammonium concentrations and to check whether ammonium was incorporated into cell biomass. For the quantification of anaerobic organic matter degradation processes along the depth transect, which are potentially coupled to nitrogen fixation, sulfate- and iron reduction rates were determined. A special emphasis was put on the relevance of bioturbation and bioirrigation on the activity of the abovementioned processes, because earlier investigations in this study area (MSM 17-4) revealed an agile macrofauna community (ghost shrimps, crabs, polychaetes) that is reworking the sediment (see also section 5.4.1).

Sampling and on-board incubations

Sediment sampling

Sediments samples were retrieved by a multicorer and from a benthic chamber of the BIGO I and BIGO II (see sections 5.4.1 and 5.4.2). Samples from multicoring (core diameter 100 mm) were used as follows: (1) one core was used for nitrogen fixation rate analysis (acetylene reduction technique, see below), CAtalyzed Reporter Deposition Fluorescence In Situ Hybridization (CARD-FISH), and RNA/DNA samples, (2) one core was used for sulfate reduction rate measurements (radiotracer method, see below), (3) one core for iron reduction rate measurements (DIC method, see below), (4) a fourth core was used for chlorophyll determination as a measure of bioturbation activity, (5) a fifth core was used for bioturbation and bioirrigation analyzes using glass beads and bromide amendments (see section 5.4.1). At two stations, a replicate multicorer core was used for: $^{15}N_2$-determination of nitrogen fixation, and two ammonium incubation experiments (see below). Samples from the benthic chamber were used in the following way: Firstly, one large core (diameter 60 mm) served for nitrogen fixation rate analyses deploying the acetylene reduction technique (see below), CARD-FISH, and RNA/DNA samples. Secondly, a small core (diameter 26 mm) was used for sulfate reduction rate measurements (radiotracer method, see below). All sampling details are provided in Table A9 (Appendix).

Nitrogen fixation sampling and incubations

At six selected stations (see Table A9, Appendix), one multicorer was used for the quantification of benthic nitrogen fixation rates via the acetylene reduction method (Stewart et al., 1967; Capone, 1993), CARD-FISH (sediment was frozen at -20°C) (Pernthaler et al., 2002), and RNA/DNA for later sequence analysis of the nifH gene pool and subsequent qPCR (sediment was frozen at -80°C). The following sampling scheme was used for multicorer sediments: 0–6 cm sediment depth in 1-cm intervals, 6–10 cm sediment depth in 2-cm intervals, and 10–20 cm sediment depth in 5-cm intervals. Push cores from the benthic chamber were sliced in 5 cm intervals (0-15 cm). For the determination of nitrogen fixation rates, 10 cm^{-3} sediment per depth interval were added into 60 ml serum vials (triplicates), crimp sealed under N_2 atmosphere and 5 ml C_2H_2 were injected. The acetylene reduction was followed over a week (4-5 time points) by injecting 100 µl gas headspace in a gas chromatograph with a flame ionization detector onboard. During incubation, all samples were kept in the dark and at in-situ temperature (12°C, based on CTD data).

Two stations along the depth transect (Table A9, Appendix) were selected for $^{15}N_2$ incubation experiments (Holtappels et al., 2011). Therefore, one multicorer core was sliced in the same sampling scheme as mentioned above and 10 cm^{-3} sediment per depth were added to a 15 ml serum vial (4 replicates) and filled up with anoxic seawater collected from supernatant of the core. The vials were crimp sealed air bubble-free and two replicates per depth were injected with 300 µl $^{15}N_2$ while the other two replicates served as control without $^{15}N_2$ injection. In the home laboratory two replicate samples (1 including $^{15}N_2$ and 1 without) will be collected at two time points (12 and 16 weeks) for later determination of $\delta^{15}N$ on a mass spectrometer and by Nano Secondary Ion Mass Spectrometry (NanoSIMS).

Ammonium incubation and inhibition

In order to check the inhibition of nitrogen fixation by ammonium, two multicorer cores were taken at selected stations (Table A9, Appendix). In the first experiment, the top 5 cm of one multicorer core were mixed and 9 cm^{-3} sediment were added to a 60 ml serum vial, as well as 3 ml anoxic seawater from the top of the sediment core. Then different ammonium concentrations (0, 25, 50, 100, 500, 2500, and 5000 µmol) were applied to the sediment slurries and the nitrogenase activity was examined. The procedure followed the protocol of the acetylene reduction assay as described above. For the second experiment, labeled ammonium ($^{15}NH_4^+$) was used to check whether bacteria incorporate ammonium into their biomass. Therefore, the top 5 cm of one multicorer core were mixed and 9 cm^{-3} sediment were added to a 15 ml serum vial. The remaining volume was filled with anoxic seawater and different $^{15}NH_4^+$ concentrations (500, 1000, 1500 µmol l^{-1}). Two replicates per concentration included $^{15}NH_4^+$ and two replicates did not contain $^{15}NH_4^+$. The further processing will follow the same procedure as described for the $^{15}N_2$ labeling experiment.

Sulfate reduction sampling and incubations

Multicorer cores and benthic chambers were sub-sampled with 2 and 1, respectively, smaller subcores (internal diameter = 26 mm, length = 300 (MUC) and 200 (BIGO) mm), which were sealed with rubber stoppers. Carrier-free $^{35}SO_4^{2-}$ (dissolved in water, injection volume = 6 µl, activity = 120 kBq, specific activity = 37 TBq $mmol^{-1}$) was injected at 1 cm intervals according to the whole core injection method of Jørgensen (1978). The cores were incubated in the dark at 12 °C for ca. 12-18 h. After incubation, sediment cores were sectioned into 1-cm intervals and transferred into 50 ml plastic centrifuge vials filled with 20 ml zinc acetate (20% w/w). Control samples obtained from additional sub-cores were first fixed before addition of tracer. Further processing of the samples will proceed in the home laboratory.

Iron reduction sampling and incubations

Iron reduction activity is measured indirectly by subtracting sulfate reduction activity from total dissolved inorganic carbon (DIC) production in anoxic sediments (Vandieken et al. 2006). Per station (Table A9, Appendix) one multicorer core was sliced into 5-cm intervals in the upper 25 cm. Sediment was filled under a constant stream of N_2 into gastight plastic bags in a cold room (12°C). The incubation bags were closed (without gas phase) and incubated at 12°C. Over a period of 14 d, subsamples were withdrawn 5 times from each bag. Porewater from the bags was obtained by a porewater press under N_2 pressure through GF/F filters. Porewater (0.5-1 ml) was acidified with 40µl 6M HCl to preserve samples for Fe^{2+} analyzes. For DIC analyzes, 1.8 ml aliquots were collected in glass vials without headspace and capped with Viton septa; these were fixed with $HgCl_2$, and stored at 4°C until analysis. Sulfate reduction in the anoxic bags was determined at each sampling time point in subsamples incubated with 120 kBq $^{35}SO_4^{2-}$ radiotracer (see above) in 5 ml glass tubes. After ca. 12-18 hrs, the incubations were stopped with 20% Zn acetate (see above). Further processing of the samples will proceed in the home laboratory.

Chlorophyll

The distribution of fresh chlorophyll in sediments provides information about bioturbation activity. For determinations, one multicorer core per station (Table A9, Appendix) was completely sectioned into 2-cm intervals. 2 cm^{-3} sediment of each section was transferred into 15 ml plastic centrifuge vials, closed, wrapped in aluminum foil (light protection) and frozen at -20°C. Samples will be further analyzed in the home laboratory.

5.4.4 Onboard whole-core nutrient release experiments

(Ulrike Lomnitz, Andrew W. Dale, Stefan Sommer, Sven Trinkler, Bettina Domeyer, Verena Thoenissen)

During this cruise two ex situ experiments were conducted onboard to test the effect of anoxia on the nutrient release from Mauritanian upper slope and shelf sediments.

Experimental set up

Undisturbed sediments were sampled using the multiple corer (MUC) at 46 and 237 m water depth, Table A10. These sites were chosen according to total oxygen uptake rates and sediment characteristics known from the previous cruise MSM 17 (March/April 2011). Beforehand, the MUC liners were prepared with calibrated oxygen sensitive spots for non-invasive O_2 measurements during the entire experiment. After the MUC deployment, three replicate sediment cores (A, B, and C) were brought to the cold room kept at in situ temperature (10 – 12°C) and were allowed to stand (while stirring) for at least 24h before the experiment was started.

The experimental set up and scheme is shown in Figure 5.4.4.1. Core A and B were kept oxic for approximately 20 h before the oxygen concentration was lowered by pumping argon gas into the overlying bottom waters. The anoxic phase of core A and B was maintained for at least 9.5 days before core A was sliced for pore water analyses and solid phase sampling. Core B was oxygenated again and kept under oxic conditions for approximately 3 days. Core C was a control core at an oxygen concentration maintained similar to the in situ oxygen concentration of the bottom water. The enclosed waterbody was ventilated with air or argon to regulate the oxygen concentrations. During the experiment duration of 14.5 days, water samples were taken every 4 h. After each sampling, the water volume equivalent to the sample volume of ~ 20 ml was refilled with the bottom water from the reservoir bags.

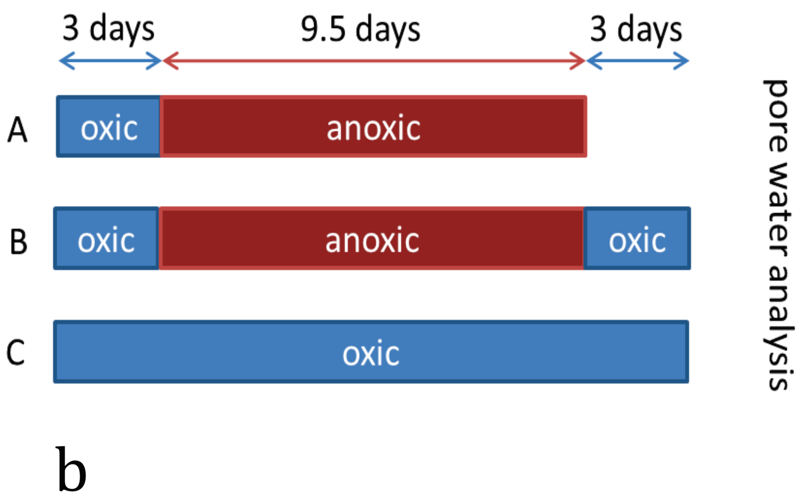

Fig. 5.4.4.1 a. Experimental set up to study the effects of anoxia on sediment nutrient release. Photo: U. Lomnitz, b. An experimental series consisted of three cores from the same sampling site. All cores were kept oxic for 24 h and then oxygen was removed in core A and B. Core C was a control core. The anoxic period of core A and B lasted for ca. 9.5 days. Core A was sliced for pore water analysis after the anoxic phase, while core B was oxygenated again and kept oxic for 3 more days and then sliced with core C for pore water and solid phase analysis.

Measurements of NO_2^-, NO_3^-, PO_4^{3-} and SiO_2 in the water samples were performed on-board once a day using a QuAAtro autoanalyzer (Seal Analytical) with a precision of ±0.1 µmol l^{-1}, ±0.1 µmol l^{-1}, ±0.2 µmol l^{-1} and ±0.24 µmol l^{-1}, respectively. For ferrous iron concentration analysis, subsamples of 0.5 to 1 ml were complexed with Ferrozin and determined photometrically. Sample cups where flushed with Argon after filling to avoid oxidation effects. Ammonium was also analyzed photometrically from subsamples of 1 to 5ml as described in section 5.4.1. Additionally, sub samples of 1 to 3 ml where acidified with suprapure HCl for onshore ICP-OES analyses of major ions and trace elements. The pore water and solid phase sampling was conducted in the same manner as described in the section 5.4.1.

Preliminary onboard results

Nutrient time series

Water sampling during the experiment series I with sediments from 237m water depth reveal a strong dependence of PO_4^{3-}, Fe^{2+}, NO_3^-, NO_2^- and NH_4^+ on the oxygen concentration of the enclosed waterbody (Figure 5.4.4.2).

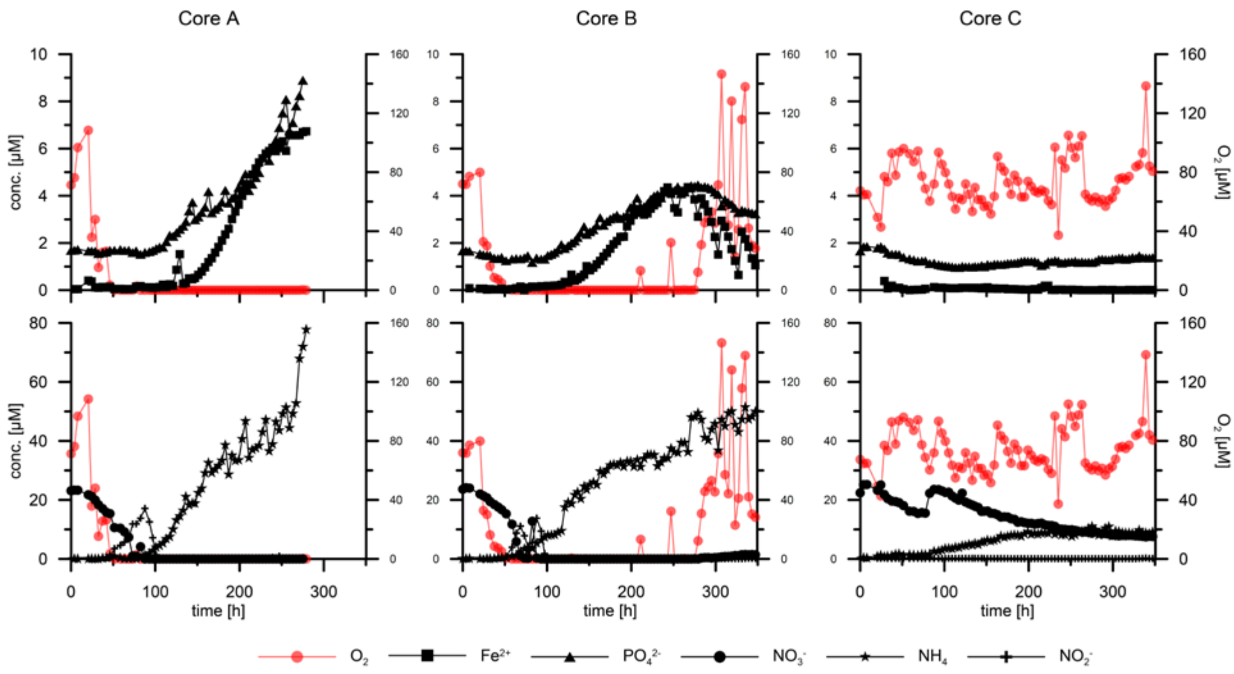

Fig. 5.4.4.2 Time course of O_2, Fe_2^+, PO_4^{3-}, NO_3^-, NO_2^-, and NH_4^+ levels in the enclosed waterbody of core A, B, and C during the experiment II conducted on sediments obtained from 237 m water depth.

Porewater and solid phase sampling

For comparing pore water profiles of core A and B it should be kept in mind that core A was sliced directly after the anoxic phase while core B was sliced after an an oxic period subsequent to an anoxic phase (Figure 5.4.4.3). Profiles of MUC8 which was not experimentally manipulated are shown as natural background. The effect of anoxia in core A and B became obvious as NH_4^+, Fe^{2+}, PO_4^{3-} as well as total alkalinity (TA) profiles showed peaks close to the sediment surface. Core A showed surface concentration peaks due to Fe^{2+} and PO_4^{3-} release during anoxic conditions. In core B surface peaks of PO_4^{3-} and Fe^{2+} were much smaller indicating oxygenated pore water conditions at the sediment surface. In contrast to the manipulated cores A and B, the reference core (MUC 8) showed a distinct iron reduction zone below the sediment surface.

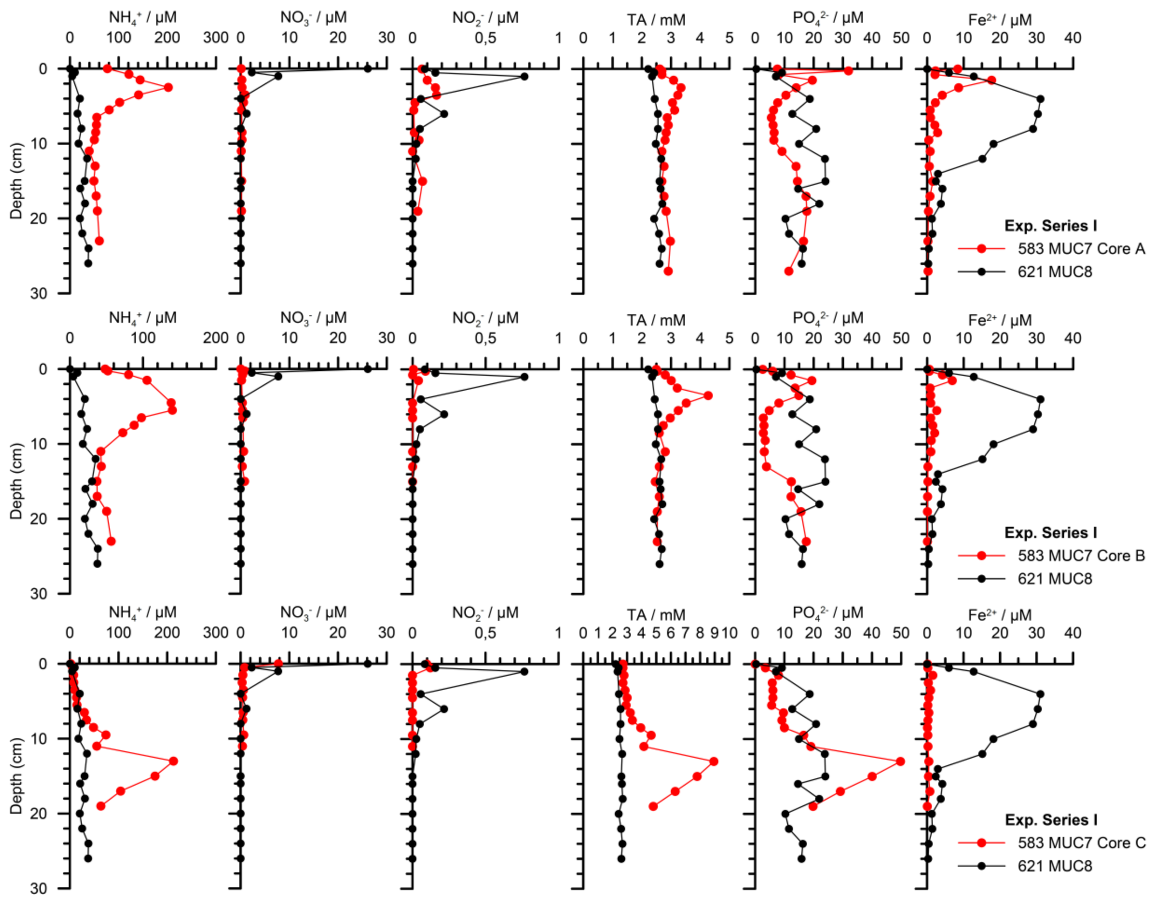

Fig. 5.4.4.3 Pore water profiles of core A, B and C from the experiment series I in comparison with reference core MUC8 from the same water depth.

5.5 Expected Results

(Stefan Sommer, shipboard scientific party)

All planned measurements and investigations were conducted successfully. To achieve the scientific aims, oceanographical investigations, geochemical measurements in the water column and the benthos as well as microbiological studies were conducted coherently. For selected sites along the depth transect at 18°20'N a complete data set is available from all scientific groups. From the combination of the different results of each discipline during M107 a high degree of synergy can be expected. At the southern working area at 18°20'N the upwelling of cold, nutrient-rich deep water is strongly seasonal, predominating from April until December. This cruise took place just at the transition between upwelling and non-upwelling conditions and the obtained data will be interpreted in conjunction with data obtained in March/April 2011 (Cruise MSM 17/4, PI O. Pfannkuche) during upwelling conditions. This allows addressing the following key questions and problems that are central to the Kieler SFB754 and to research in oxygen minimum zones in general:

i. to assess potential feedback of benthic nutrient release on processes in the water column and primary productivity in the surface water during different upwelling conditions. The source strength of nutrient release at different sites in response to variable bottom water O_2, NO_3^-, and NO_2^- conditions and availability of sedimentary organic carbon was intensively investigated in situ using state of the art benthic landers, pore water gradients and onboard nutrient release experiments.

ii. Fluxes across the sediment water interface in combination with water column nutrient profiles, radiotracer profiles and hydrographical data as well as micro-structure turbulence data will allow to address trace metal distribution and the fate of nutrients once they are released from the seafloor. Major transport processes such as upwelling and vertical mixing of the nutrients to the surface mixed layer will be determined;

iii. Benthic and pelagic microbiological/virologcial studies conducted during the cruise will allow the identification of the different processes involved in benthic-pelagic carbon, N and P turnover. Measurements were conducted to determine whether fractionation by benthic organisms takes place during N turnover.

6 Ship's meteorological station

On the 31th of May at 11:00 RV METEOR left the harbor of Fortaleza to an expedition to Mauritania. At first RV METEOR cruised along the southern fringe of a tropical trough experienced moderate to fresh southeasterly trade winds with 4 to 5 Bft and a sea of 1.5 to 2m. While cruising to the northeast toward the equator the southeasterly trade winds subsided gradually. Along the equator only east to southeast winds about 3 Bft were experienced. From the 01th to the 03th of June RV METEOR crossed the ITC experiencing a few strong showers developing from convective clouds. On the 2th about 20:52 board time a peak rainfall intensity of 105mm/h was reached. In the vicinity of showers gust to 8 Bft were measured. Otherwise the wind around the ITC was weak and the seas only reached 1 to 1.5m. From the 5th of June the trade wind increased to 4 to 5 Bft from a mostly northerly direction. The sea gradually increased to 1.5m. During the trip to Mauritania the trade wind inversion increased further with no precipitation developing. At the 8th close to Mauritania Sahara dust in higher elevations caused the visibility to decrease and to dust deposits. The humidity at about 80% decreased to 70%. The air temperature increased to 23 to 24 ° C. Close to Mauritania in the southern working area the coastal induced northwesterly winds showed 4 to 5 Bft until the 15th. The sea reached a height of 1.5 m. On the 9th to the 10th however a low pressure trough over the research area, temporarily led to a wind force 6. On the 16th in the northern work area off Mauritania (20 °north) the northerly trade winds increased to 5 to 6 Bft without land protection. During the 16th to 18th there was an unscheduled transit to the Cape verde Island Sala and back to the work area. RV METEOR experienced mostly northerly winds of force 5 to 6 Bft. The 2 to 2.5 m sea with a northwesterly swell showed a quite shaky RV METEOR. During the transit below the trade wind inversion the classical trade cloudiness developed. On the 19th wind force 6 and sea of 2m hampered accessing the gliders with the dinghy. There was a diurnal circle for the wind which decreased mostly during the afternoons, off the coast the diurnal variation lasted only shortly. On that cloud-free day the sun was shining for 11 hours and 41 minutes. As of the 20th the pressure differences between the Azores high and a thermal low over Africa increased slightly. Hence until the 28th a mostly steady wind from North to northwest with force 6, temporarily Bft 5, was experienced. The significant wave height only reached up to 1.5 to 2m. On the 23th a low was over Mauritania causing Sahara dust to rise with the consequence to darken the sun. At times, the visibility was poor and red-brown dust was deposited on the ship. During the evening hours the wind dropped to 3 Bft for a time as well as an overnight low crossed the area to the 25th. As of the 28th in the northern area of the working area the water temperature cooled from 21°C to 18°C and therefore also the air temperature. In the evening hours the wind increased to a power of 7 Bft with a sea of 2 to 3m. On the 29th the planned recovery of the glider with the dinghy was postponed to the 30th due to the noticeably anticipated decrease of wind within the center of a low.

From the 30th RV METEOR was on transit to Las Palmas. Until late on the 1st of July the wind blew weak to moderate from the south before shifting northeast and increasing to 6 to 7 Bft with a sea of 3 to 4m. On the 3rd of July RV METEOR reached the port of Las Palmas. The data of the shipboard meteorological station are available from the DWD as well as from the GEOMAR data storage center.

7 Stationlist M107

station # METEOR	date	time (UTC)	gear #	Position		depth (m)	remarks
				Lat. (N)	Long. (W)		
M107_435	01.06.	16:06	fish 01	00°38.42'	35°39.59'	4449	deployment
M107_436	01.06.	17:30	uCTD 01	00°29.00'	35°30.418'	4501	
M107_437	01.06.	19:32	uCTD 02	00°13.89'	35°15.48'	4501	
M107_438	01.06.	21:30	uCTD 03	00°02.23'	34°59,54'	4522	
M107_439	02.06.	00:03	uCTD 04	00°21.22'	34°40.77'	4525	
M107_440	02.06.	01:26	uCTD 05	00°32.28'	34°30.17'	4200	
M107_441	02.06.	03:54	uCTD 06	00°51.60'	34°11.09'	3920	renewed line & splices
M107_442	02.06.	05:32	uCTD 07	01°04.50'	33°58.34'	3675	
M107_443	02.06.	07:28	uCTD 08	01°19.61'	33°43.42'	3716	
M107_444	02.06.	09:34	uCTD 09	01°36.07'	33°27.16'	3598	
M107_445	02.06.	11:52	uCTD 10	01°54.30'	33°09.15'	3711	
M107_446	02.06.	13:25	uCTD 11	02°06.73'	32°56.87'	3130	
M107_447	02.06.	15:31	uCTD 12	02°23.68'	32°40.12'	3697	
M107_448	02.06.	17:35	uCTD 13	02°39.78'	32°24.20'	3240	
M107_449	02.06.	19:32	uCTD 14	02°54.71'	32°09.44'	3622	
M107_450	02.06.	21:35	uCTD 15	03°10.05'	21°52.40'	3000	
M107_451	02.06.	23:33	uCTD 16	03°25.17'	31°39.32'	3159	
M107_452	03.06.	01:21	uCTD 17	03°39.71'	31°24.93'	2692	
M107_453	03.06.	04:03	uCTD 18	03°59.08'	31°05.75'	3850	
M107_454	03.06.	05:28	uCTD 19	04°09.83'	30°55.11'	3248	
M107_455	03.06.	07:29	uCTD 20	04°25.13'	30°39.24'	3207	
M107_456	03.06.	09:38	uCTD 21	04°41.26'	30°21.92'	3599	
M107_457	03.06.	11:31	uCTD 22	04°54.84'	30°07.32'	3916	
M107_458	03.06.	13:22	uCTD 23	05°07.52'	29°53.69'	3870	
M107_459	03.06.	16:08	uCTD 24	05°28.47'	29°30.87'	3685	
M107_460	03.06.	17:26	uCTD 25	05°38.62'	29°18.42'	3620	
M107_461	03.06.	19:38	uCTD 26	05°54.74'	29°02.89'	4220	
M107_462	03.06.	21:29	uCTD 27	06°08.22'	28°48.33'	4236	
M107_463	03.06.	23:29	uCTD 28	06°22.67'	28°32.82'	4324	
M107_464	04.06.	02:42	uCTD 29	06°38.48'	28°15.77'	4054	
M107_465	04.06.	03:26	uCTD 30	06°50.52'	28°02.79'	4390	
M107_466	04.06.	05:24	uCTD 31	07°03.84'	27°48.42'	4464	
M107_467	04.06.	07:28	uCTD 32	07°17.56'	27°33.62'	4742	
M107_468	04.06.	09:34	uCTD 33	07°31.50'	27°18.56'	4546	
M107_469	04.06.	11:33	uCTD 34	07°44.48'	27°04.54'	4591	
M107_470	04.06.	13:31	uCTD 35	07°57.44'	26°50.53'	4252	
M107_471	04.06.	15:32	uCTD 36	08°11.17'	26°35.68'	5100	
M107_472	04.06.	17:35	uCTD 37	08°25.29'	26°20.40'	4740	
M107_473	04.06.	19:36	uCTD 38	08°39.36'	26°05.17'	4939	
M107_474	04.06.	21:30	uCTD 39	08°52.39'	25°51.04'	5137	
M107_475	04.06.	23:33	uCTD 40	09°05.72'	25°36.60'	5100	
M107_476	05.06.	01:35	uCTD 41	09°19.58'	25°21.56'	4860	
M107_477	05.06.	03:23	uCTD 42	09°31.99'	25°08.09'		

station #	**date**	**time**	**gear #**	**Position**		**depth**	**remarks**
METEOR		**(UTC)**		**Lat. (N)**	**Long. (W)**	**(m)**	
M107_478	05.06.	05:31	uCTD 43	09°46.31'	24°52.54'	5241	
M107_479	05.06.	07:31	uCTD 44	10°00.07'	24°37.57'		
M107_480	05.06.	09:30	uCTD 45	10°13.97'	24°22.45'	5029	
M107_481	05.06.	11:30	uCTD 46	10°30.09'	24°04.89'	4739	
M107_482	05.06.	14:19	uCTD 47	10°47.55'	23°45.88'	5204	
M107_483	05.06.	15:40	uCTD 48	10°56.88'	23°35.70'	5025	
M107_484	05.06.	17:31	uCTD 49	11°09.86'	23°21.54'	5147	
M107_485	05.06.	20:37	CTD 01	11°27.27'	22°59.90'	5088	
M107_486	05.06.	20:50	CTD 02	11°27.27'	22°59.90'	5090	
M107_487	06.06.	01:28	uCTD 50	11°46.58'	22°44.34'	5008	
M107_488	06.06.	03:34	uCTD 51	12°02.40'	22°29.72'	4950	
M107_489	06.06.	05:29	uCTD 52	12°16.64'	22°16.54'	4898	
M107_490	06.06.	07:37	uCTD 53	12°32.35'	22°01.99'	4823	
M107_491	06.06.	09:23	uCTD 54	12°45.21'	21°50.06'	4765	
M107_492	06.06.	11:52	uCTD 55	13°03.92'	21°35.21'	4685	
M107_493	06.06.	13:47	uCTD 56	13°19.22'	21°25.58'	4660	
M107_494	06.06.	15:45	uCTD 57	13°34.87'	21°15.71'	4531	
M107_495	06.06.	17:33	uCTD 58	13°48.83'	21°06.90'	4437	
M107_496	06.06.	19:32	uCTD 59	14°04.07'	20°57.27'	4319	
M107_497	06.06.	21:34	uCTD 60	14°19.59'	20°47.46'	4256	
M107_498	06.06.	23:41	uCTD 61	14°35.96'	20°37.12'	4169	
M107_499	07.06.	01:31	uCTD 62	14°50.36'	20°27.96'	4040	
M107_500	07.06.	03:34	uCTD 63	15°07.01'	20°17.52'	3950	
M107_501	07.06.	05:31	uCTD 64	15°23.09'	20°07.17'	3717	
M107_502	07.06.	07:35	uCTD 65	15°39.55'	19°56.69'	3529	
M107_503	07.06.	09:32	uCTD 66	15°54.30'	19°47.29'	3518	
M107_504	07.06.	12:28	uCTD 67	16°13.09'	19°29.28'	3470	
M107_505	07.06.	13:37	uCTD 68	16°18.03'	19°19.92'	3420	
M107_506	07.06.	15:35	uCTD 69	16°26.85'	19°03.19'	3360	
M107_507	07.06.	17:36	uCTD 70 - 1	16°36.34'	18°45.17'	3246	Did not work. Not saved
M107_508	07.06.	18:05	uCTD 70 - 2	16°38.69'	18°40.72'	3211	
M107_509	07.06.	19:56	uCTD 71	16°40.32'	18°37.62'	3187	
M107_510	07.06.	21:29	uCTD 72	16°56.50'	18°09.10'	2888	
M107_511	07.06.	23:33	uCTD 73	17°05.87'	17°48.64'	2650	
M107_512	08.06.	01:33	uCTD 74	17°15.33'	17°27.99'	2380	
M107_513	08.06.	03:28	uCTD 75	17°25.55'	17°08.06'	1807	
M107_514	08.06.	05:31	uCTD 76	17°36.58'	16°46.51'	957	
M107_515	08.06.	17:10	POZ Lander 01	18°16'	16°19'	50	DOC Underway Probe, Ruth Flerus
M107_516	08.06.	18:34	CTD 03	18°15.201'	16°29.944'	92	LOC test
M107_517	08.06.	21:48	CTD 04	18°15.133'	16°27.02'	92	
M107_518	08.06.	22:54	MSS 01	18°15.11'	16°27.06'	92 – 95	
M107_519	09.06.	00:11	CTD 05	18°14.333'	16°30.996'	169	
M107_520	09.06.	01:59	MSS 02	18°14.37'	16°31.03'	170	

station #	**date**	**time**	**gear #**	**Position**		**depth**	**remarks**
METEOR		**(UTC)**		**Lat. (N)**	**Long. (W)**	**(m)**	
M107_521	09.06.	03:32	CTD 06	18°13.089'	16°33.31'	238	
M107_522	09.06.	05:21	MSS 03	18°13.43'	16°33.43'	314	
M107_523	09.06.	06:32	CTD 07	18°12.51'	16°35.72'	424	
M107_524	09.06.	08:11	TV-MUC 01	18°09.991'	16°45.023'	1108	
M107_525	09.06.	10:05	TV-MUC 02	18°09.997'	16°45.031'	1098	aborted, no video
M107_526	09.06.	10:51	Trace Metal CTD 01	18°09.47'	16°45.02'	1091	
M107_527	09.06.	14:00	BIGO II 01	18°10'	16°44.99'	1096	deployment
M107_528	09.06.	15:52	Glider 01	18°12.11'	16°45.03'	1110	deployment
M107_529	09.06.	17:37 - 21:05	in situ pumps 01	18°11.0'	16°45.0'	1104	
M107_530	10.06.	00:01	CTD 08	18°02.00'	17°10.01'	2025	
M107_531	10.06.	02:12	APEX Float 01	18°00.071'	17°12.141'	2050	
M107_532	10.06.	02:27	APEX Float 02	18°00.442'	17°12.221'	2050	
M107_533	10.06.	03:59	CTD 09	18°04.99'	17°00.01'	1760	
M107_534	10.06.	08:10	TV-MUC 03	18°11.288'	16°39.328'	786	
M107_535	10.06.	11:00	Mooring 01	18°12.00'	16°34.32'	356	
M107_536	10.06.	13:36 - 15:30	Glider 02	18°13.29'	16°39.36'	740	deployment
M107_537	10.06.	17:21 - 19:59	in situ pumps 02	18°11.30'	16°39.28'	781	
M107_538	10.06.	20:17	CTD 10	18°11.30'	16°39.28'	781	
M107_539	10.06.	21:21	Trace Metal CTD 02	18°11.31'	16°39.22'	781	
M107_540	10.06.	23:28	MSS 04	18°10.00'	16°44.94'	1093	
M107_541	11.06.	01:26	CTD 11	18°09.99'	16°14.99'	1095	
M107_542	11.06.	03:25	MSS 05	18°07.84'	16°51.40'	1448	
M107_543	11.06.	05:32	CTD 12	18°07.79'	16°51.39'	1453	
M107_544	11.06.	08:03	BIGO II 01	18°09.73'	16°44.97'	1095	recovery
M107_545	11.06.	09:22 - 12:21	in situ pumps 03	18°11.0'	16°45.0'	1104	
M107_546	11.06.	12:40	CTD 13	18°11.00'	16°45.01'	1103	
M107_547	11.06.	14:27	BIGO-I 01	18°11.31'	16°39.335'	787	deployment. slightly touched
M107_548	11.06.	18:53	Sinkstofffalle 03	18°08.20'	16°52.36'	1497	
M107_549	11.06.	19:23	CTD 14	18°07.01'	16°52.57'	1600	
M107_550	11.06.	20:39	in situ pumps 04	18°07.01'	16°52.57'	1602	
M107_551	12.06.	01:36	MSS 06	18°09.66'	16°47.84'	1242	
M107_552	12.06.	03:37	CTD 15	18°09.00'	16°48.32'	1237	
M107_553	12.06.	05:07	Trace Metal CTD 03	18°10.03'	16°45.03'	1098	
M107_554	12.06.	08:03	MUC 05	18°12.504'	16°35.583'	412	lots of bioturbation
M107_555	12.06.	08:50	MUC 06	18°12.507'	16°35.583'	412	
M107_556	12.06.	10:00	Glider 03	18°10.48'	16°35.59'	438	deployment
M107_557	12.06.	12:59	BIGO-II 02	18°12.504'	16°35.585'	412	deployment
M107_558	12.06.	14:15	Mooring 02	18°14.06'	16°31.03'	164	deployment
M107_559	12.06.	15:06	CTD 16	18°14.00'	16°31.00'	166	
M107_560	12.06.	18:02	CTD 17	18°14.00'	16°31.00'	166	

station # METEOR	date	time (UTC)	gear #	Position Lat. (N)	Long. (W)	depth (m)	remarks
M107_561	12.06.	19:05	MSS 07	18°14.02'	16°31.03'	167	
M107_562-1	12.06.	20:36	Trace Metal CTD 04	18°13.98'	16°30.93'	165	did not release the bottles. -> 562-2
M107_562-2	12.06.	21:15	Trace Metal CTD 05	18°14.00'	16°31.01'	167	
M107_563	12.06.	22:00	in situ pumps 05	18°4.070'	16°31.102'	174	
M107_564	13.06.	00:29	MSS 08	18°13.71'	16°31.96'	190	
M107_565	13.06.	01:45	CTD 18	18°14.67'	16°32.54'	302	
M107_566	13.06.	02:55	MSS 09	18°13.01'	16°33.30'	240	
M107_567	13.06.	04:21	MSS 10	18°12.97'	16°33.27'	244	
M107_568	13.06.	05:27	CTD 19	18°13.02'	16°33.26'	240	
M107_569	13.06.	08:00	BIGO-I 01	18°10.836'	16°39.229'	789	recovery
M107_570	13.06.	09:14 - 11:40	in situ pumps 06	18°11.30'	16°39.30'	784	
M107_571	13.06.	13:35	Glider 04	18°13.13'	16°39.71'	729	deployment
M107_572	13.06.	16:08	Profiler 01	18°14.195'	16°31.008'	167	deployment. voltametry not calibrated. LOC.
M107_573	13.06.	17:51	MSS 11	18°16.90'	16°19.00'	47	
M107_574	13.06.	20:13	CTD 20	18°17.29'	16°18.91'	46	
M107_575	13.06.	20:40	Trace Metal CTD 06	18°17.29'	16°18.91'	46	
M107_576	14.06.	00:46	CTD 21	18°10.37'	16°43.03'	1019	
M107_577	14.06.	00:46 - 04:25	MSS 12	18°11.61'	16°40.46'	888 – 210	front transect
M107_578	14.06.	04:45	CTD 22	18°13.60'	16°31.76'	183	
M107_579	14.06.	07:11	CTD 23	18°12.33'	16°36.07'	455	
M107_580	14.06.	08:08	BIGO-II 02	18°12.273'	16°95.530'	410	recovery
M107_581	14.06.	09:00 - 12:30	in situ pumps 07	18°12.514'	16°35.588'	412	
M107_582	14.06.	13:58	CTD 24	18°13.02'	16°33.14'	231	
M107_583	14.06.	13:51	MUC 07	18°12.998'	16°33.197'	237	
M107_584	14.06.	15:30	Profiler 01	18°14.195'	16°31.008'	167	
M107_585	14.06.	17:05	DOS-Lander 01	18°13.985'	16°26.983'	92	only ADCP
M107_586	14.06.	19:02	CTD 25	18°10.87'	16°41.58'	950	
M107_587	14.06.	20:19	CTD 26	18°10.88'	16°41.59'	950	
M107_588	14.06.	21:21	MSS 13	18°10.89'	16°41.59'	953	
M107_589	14.06.	23:58	MSS 14	18°11.95'	16°37.06'	988	
M107_590	15.06.	01:13	CTD 27	18°13.00'	16°37.59'	620	
M107_591	15.06.	02:46	MSS 15	18°12.94'	16°35.89'	434	
M107_592	15.06.	04:42	CTD 28	18°12.58'	16°35.56'	410	
M107_593	15.06.	05:55	MSS 16	18°13.64'	16°31.74'	183	
M107_594	15.06.	07:00	CTD 29	18°13.57'	16°31.74'	183	
M107_595	15.06.	08:17	CTD 30	18°12.29'	16°36.14'	460	
M107_596	15.06.	10:00	in situ pumps 08	18°12.286'	16°36.125'	461	
M107_597	15.06.	12:47	Sinkstofffalle 04	18°12.41'	16°36.22'	470	
M107_598	15.06.	14:24	BIGO I 02	18°13.286'	16°33.334'	236	depl. 50 h delay
M107_599	16.06.	07:06	MB Profil 01	19°53.76'	17°32.13'	715	

station #	**date**	**time**	**gear #**	**Position**		**depth**	**remarks**
METEOR		**(UTC)**		**Lat. (N)**	**Long. (W)**	**(m)**	
M107_600	16.06.	08:17	Mooring 03	19°54.94'	17°30.55'	148	
M107_601	16.06.	11:31	CTD 31	19°53.83'	17°32.59'	659	
M107_ 602	19.06.	14:15	Glider 05	18°30.46'	17°05.66'	1914	
M107_603	19.06.	16:07	Glider 06	18°30.44'	17°05.65'	1910	
M107_604	19.06.	21:00	Sinkstofffalle 04	18°10.589'	16°42.522'	997	recovery.
M107_605	19.06.	22:30	CTD 32	18°11.24'	16°39.31'	793	
M107_606	19.06.	23:24	Trace Metal CTD 07	18°11.25'	16°39.32'	800	
M107_607	20.06.	00:24	MSS 17	18°11.30'	16°39.33'	784	
M107_608	20.06.	02:11	MSS 18	18°12.55'	16°35.63'	415	
M107_609	20.06.	04:06	CTD 33	18°12.41'	16°35.59'	412	
M107_610	20.06.	05:32	MSS 19	18°13.01'	16°33.30'	240	
M107_611	20.06.	06:39	CTD 34	18°13.00'	16°33.29'	240	
M107_612	20.06.	07:55	TV-MUC 08	18°12.945'	16°33.153'	236	
M107_613	20.06.	08:35	TV-MUC 09	18°12.945'	16°33.154'	236	
M107_614	20.06.	09:03	BIGO I 02	18°12.95'	16°33.15'	236	
M107_615	20.06.	13:34	in situ pumps 09	18°12.444'	16°35.605'	414	
M107_616	20.06.	13:56	CTD 35	18°12.44'	16°35.61'	414	
M107_617	20.06.	15:47	BIGO II 03	18°14.397'	16°31.000'	171	
M107_618	20.06.	17:00	CTD 36	18°14.18'	16°31.00'	167	
M107_619	20.06.	17:35	Trace Metal CTD 08	18°14.18'	16°31.09'	167	
M107_620	20.06.	17:59	Trace Metal CTD 09	18°14.10'	16°31.09'	169	
M107_621	20.06.	18:47	MSS 20	18°13.19'	16°32.45'	202	
M107_622	20.06.	19:50	MSS 21	18°14.89'	16°28.80'	113	
M107_623	20.06.	21:31	CTD 37	18°14.87'	16°28.79'	112	
M107_624	20.06.	22:30 - 01:00	MSS 22	18°15.15'	16°27.99'	91-97	
M107_625	21.06.	01:36	CTD 38	18°15.16'	16°26.98'	91	
M107_626	21.06.	02:39	MSS 23	18°16.00'	16°24.09'	71	
M107_627	21.06.	05:02	CTD 39	18°15.98'	16°24.09'	72	
M107_628	21.06.	07:50	TV-MUC 10	18°15.197'	16°27.002'	90	
M107_629	21.06.	08:15	TV-MUC 11	18°15.196'	16°27.002'	91	
M107_630	21.06.	10:23	BIGO I 03	18°15.006'	16°27.010'	91	deployment
M107_631	21.06.	11:00 - 13:30	in situ pumps 10	18°14.81'	16°27.05'	92	
M107_632	21.06.	13:58	CTD 40	18°14.81'	16°27.05'	92	
M107_633	21.06.	15:10	Profiler 02	18°14.699'	16°27.005'	92	
M107_634	21.06.	16:51	CTD 41	18°11.28'	16°39.29'	784	
M107_635	21.06.	19:33	MSS 24	18°11.29'	16°39.29'	784	
M107_636	21.06.	23:12	Trace Metal CTD 10	18°09.91'	16°45.04'	1100	
M107_637	22.06.	00:47	CTD 42	18°09.91'	16°16.45'	1097	
M107_638	22.06.	02:14	CTD 43	18°09.90'	16°45.07'	1098	
M107_639	22.06.	03:02	MSS 25	18°09.93'	16°45.12'	1102	
M107_640	22.06.	05:57	MSS 26	18°14.05'	16°31.24'	173	
M107_641	22.06.	06:47	CTD 44	18°14.09'	16°31.23'	174	
M107_642	22.06.	08:00	BIGO II 03	18°14.4'	16°31.0'	174	recovery

station #	**date**	**time**	**gear #**	**Position**		**depth**	**remarks**
METEOR		**(UTC)**		**Lat. (N)**	**Long. (W)**	**(m)**	
M107_643	22.06.	09:00	in situ pumps 11	18°14.194'	16°31.034'	170	
M107_644	22.06.	12:58	CTD 45	18°14.19'	16°31.04'	168	
M107_645	22.06.	14:37	CTD 46	18°17.291'	16°18.937'	46	
M107_646	22.06.	14:39	CTD 47	18°17.291'	16°18.937'	46	
M107_647	22.06.	15:23	TV-MUC 12	18°17.297'	16°19.000'	46	
M107_648	22.06.	15:55	in situ pumps 12	18°17.279'	16°18.985'	47	
M107_649	22.06.	19:24	MSS 27	18°17.11'	16°18.84'	46	
M107_650	22.06.	21:27	CTD 48	18°17.23'	16°18.96'	46	
M107_651	22.06.	22:42	CTD 49	18°15.19'	16°27.01'	91	
M107_652	22.06.	23:19	Trace Metal CTD 11	18°15.19'	16°27.01'	91	
M107_653	22.06.	23:53	MSS 28	18°15.24'	16°27.02'	91	
M107_654	23.06.	02:20	MSS 29	18°15.97'	16°24.10'	71	
M107_655	23.06.	04:38	CTD 50	18°15.98'	16°24.10'	72	
M107_656	23.06.	05:24	MSS 30	18°16.71'	16°21.40'	61	
M107_657	23.06.	06:28	CTD 51	18°16.69'	16°21.49'	60	
M107_658	23.06.	07:48	MUC 13	18°17.299'	16°18.994'	47	
M107_659	23.06.	08:18	MUC 14	18°17.299'	16°18.994'	46	
M107_660	23.06.	09:32	BIGO I 03	18°14.763'	16°27.000'	93	
M107_661	23.06.	10:55	in situ pumps 13	18°13.102'	16°33.294'	237	
M107_662	23.06.	14:00	CTD 52	18°13.10'	16°33.30'	236	
M107_663	23.06.	14:49	mooring 04	18°14.19'	16°31'	167	deployment
M107_664	23.06.	15:45		18°14.51'	16°26.98'	92	
M107_665	23.06.	17:59	BIGO II 04	18°17.100'	16°18.997'	47	deployment
M107_666	24.06.	00:14	ARGO float 02	17°59.59'	17°18.12'	2219	
M107_667	24.06.	01:10	CTD 53	17°59.99'	17°16.99'	2165	
M107_668	24.06.	03:26	CTD 54	18°00.03'	17°17.01'	2168	
M107_669	24.06.	08:08	TV-MUC 15	18°10.001'	16°44.997'	1099	
M107_670	24.06.	10:00	in situ pumps 14	18°10.595'	16°42.479'	995	
M107_671	24.06.	15:18	TV-MUC 16	18°14.765'	16°28.759'	112	not suitable for BIGO. Coarse shell debris
M107_672	24.06.	15:52	TV-MUC 17	18°14.483'	16°29.634'	129	
M107_673	24.06.	18:14	BIGO I 04	18°14.485'	16°29.635'	131	no video depl. of BIGO. Released 2m above ground
M107_674	24.06.	19:21	in situ pumps 15	18°13.10'	16°33.30'	477	
M107_675	24.06.	21:35	CTD 55	18°13.09'	16°33.30'	238	
M107_676	24.06.	22:22	Trace Metal CTD 12	18°13.09'	16°33.30'	238	
M107_677	24.06.	23:08	MSS 31	18°13.16'	16°33.32'	237	
M107_678	25.06.	00:47	CTD 56	18°12.49'	16°35.60'	413	
M107_679	25.06.	01:31	MSS 32	18°12.54'	16°35.65'	416	
M107_680	25.06.	03:24	CTD 57	18°12.49'	16°35.60'	412	
M107_681	25.06.	04:28	MSS 33	18°14.34'	16°31.01'	169	
M107_682	25.06.	06:09	CTD 58	18°14.30'	16°31.02'	170	
M107_683	25.06.	08:02	BIGO II 04	18°16.850'	16°18.953'	53	recovery
M107_684	25.06.	10:00	in situ pumps 16	18°17.003'	16°18.97'	47	

station #	**date**	**time**	**gear #**	**Position**		**depth**	**remarks**
METEOR		**(UTC)**		**Lat. (N)**	**Long. (W)**	**(m)**	
M107_685	25.06.	12:30	TV-MUC 18	18°17.003'	16°18.976'	47	
M107_686	25.06.	13:25	TV-MUC 19	18°16.287'	16°22.910'	66	Position for BIGO II 05: 18°16.282' N, 16°22.931' W
M107_687	25.06.	15:45	Profiler 03	18°16.999'	16°18.990'	40	deployment
M107_688	25.06.	18:36	BIGO II 05	18°16.286'	16°22.932'	67	
M107_689	25.06.	20:25	CTD 59	18°12.48'	16°35.57'	412	
M107_690	25.06.	21:10	Trace Metal CTD 13	18°12.48'	16°35.57'	413	
M107_691	25.06.	22:16	MSS 34	18°12.50'	16°35.59'	413	
M107_692	26.06.	00:35	MSS 35	18°14.79'	16°28.60'	108	
M107_693	26.06.	02:49	CTD 60	18°14.790'	16°28.574'	108	
M107_694	26.06.	03:44	CTD 61	18°16.001'	16°24.106'	71	
M107_695	26.06.	04:27	MSS 36	18°15.18'	16°26.99'	91	
M107_696	26.06.	06:18	CTD 62	18°15.186'	16°26.994'	91	
M107_697	26.06.	07:53	TV-MUC 20	18°14.299'	16°30.995'	169	
M107_698	26.06.	08:30	BIGO I 04	18°14.527'	16°29.659'	130	recovery
M107_699	26.06.	09:28	TV-MUC 21	18°13.073'	16°33.340'	240	
M107_ 700	26.06.	10:17	mooring 01	18°11.92'	16°34.92'	210	
M107_ 701	26.06.	12:38	mooring 02	18°12.79'	16°31.09'	150	search
M107 _702	26.06.	15:14	mooring 04	18°13.859'	16°31.254'	168	recovery
M107_703	26.06.	16:17	DOS-Lander 01	18°13.86'	16°26.94'	91	recovery
M107_704	26.06.	18:00	in situ pumps 17	18°13.098'	16°33.306'	235	
M107_705	26.06.	21:32	CTD 63	18°13.67'	16°32.00'	188	
M107_706	26.06.	22:49	Trace Metal CTD 14	18°13.67'	16°32.00'	189	
M107_707	26.06.	23:35	MSS 37	18°13.69'	16°32.01'	188 - 230	
M107_708	27.06.	02:26	MSS 38	18°10.02'	16°44.98'	1097	
M107_709	27.06.	04:20	CTD 64	18°09.99'	16°44.97'	1095	
M107_710	27.06.	08:00	BIGO II 05	18°16.056'	16°22.836'	65	recovery
M107_711	27.06.	09:00	POZ Lander 01	18°16.0'	16°19.0'	50	
M107_712	27.06.	10:00	CTD 65	18°17.7'	16°19.0'	50	
M107_713	27.06.	10:31	Profiler 03	18°16.862'	16°18.995'	48	recovery
M107_714	27.06.	12:11	TV-MUC 22	18°13.023'	16°30.996'	163	
M107_715	27.06.	14:48	Glider 03	18°09.43'	16°37.43'	236	recovery
M107_716	27.06.	15:32	Glider 01	18°07.25'	16°37.32'	162	recovery
M107_717	27.06.	17:00	mooring 02	18°13.27'	16°31.04'	164	search. Not found
M107_718	28.06.	07:53	mooring 03	19°53.48'	17°33.77'	835	search. Not found
M107_719	28.06.	12:00	CTD 66	19°53.68'	17°49.24'	721	
M107_720	28.06.	13:54	ADCP/uCTD sect. 01	19°55.02'	17°24.87'	119	
M107_721	28.06.	17:37	ADCP/uCTD sect. 02	19°29.97'	17°52.43'	2025	
M107_722	28.06.	21:40	ADCP/uCTD sect. 03	19°53.19'	17°27.28'	686	
M107_723	29.06.	00:45	CTD 67	19°38.99'	17°42.02'	1909	
M107_724	29.06.	01:43	CTD 68	19°40.81'	17°40.13'	1787	
M107_725	29.06.	02:34	CTD 69	19°42.56'	17°38.31'	2021	
M107_726	29.06.	03:28	CTD 70	19°44.35'	17°36.45'	1878	
M107_727	29.06.	04:20	CTD 71	19°46.08'	17°34.58'	1493	

station # METEOR	date	time (UTC)	gear #	Position Lat. (N)	Long. (W)	depth (m)	remarks
M107_728	29.06.	05:26	CTD 72	19°49.73'	17°30.84'	1180	
M107_729	29.06.	06:29	CTD 73	19°53.32'	17°27.10'	623	
M107_730	29.06.	06:56	ADCP/uCTD sect. 04	19°53.31'	17°27.05'	570	
M107_731	29.06.	09:08	ADCP/uCTD sect. 05	19°39.00'	17°42.05'	1910	
M107_732	29.06.	12:05	ADCP/uCTD sect. 06	19°53.37'	17.27.13'	650	
M107_733	29.06.	15:04	ADCP/uCTD sect. 07	19°38.95'	17°42.03'	2060	
M107_734	29.06.	17:55	ADCP/uCTD sect. 08	19°53.28'	17°27.09'	778	
M107_735	29.06.	21:17	ADCP/uCTD sect. 09	19°38.98'	17°42.04'	1907	
M107_736	29.06.	23:36	mooring 03	19°50.15'	17°30.22'	1200	
M107_737	30.06.	02:49	ADCP 01	19°50.18'	17°30.16'	980 - 2033	ADCP was off.
M107_738	30.06.	07:12	Glider 02	19°39.08'	17°47.44'	1894	recovery
M107_739	30.06.	08:05	Glider 06	19°42.77'	17°38.17'	1718	recovery
M107_740	30.06.	08:57	Glider 05	19°45.77'	17°33.82'	1673	recovery
M107_741	30.06.	10:20	mooring 03	19°48.823'	17°26.444'	1237	recovery

Abbreviations:

Water column: **CTD:** CTD watersampling rosette, **Trace Metal CTD:** CTD watersampling rosette specifically designed for the measurement of trace metals**, u-CTD:** underway CTD, **fish:** towed fish for continuous surface water sampling, **MSS:** Microstructure CTD for the measurement of physical properties and turbulence, **Glider**: for the measurement of physical properties, turbulence, O_2, nitrate, **in situ pumps**: radiotracer and C,N,P composition of particles, **mooring**: currents (ADCP)

Benthos: **BIGO-I, BIGO-II** (Biogeochemical observatory): Geochemistry, Microbiology, flux measurements, **TV-MUC** (Multiple corer video-guided): Geochemistry, Microbiology, Foraminifera*,* **Profiler**: Lander equipped with voltammetry, Lab on a Chip, CTD, turbidity, **POZ Lander** (Physical Oceanography Lander): ADCP current measurements.

8 Data and Sample Storage and Availability

The data were collected within the Kiel Sonderforschungsbereich (SFB) 754. In Kiel a joint data management team of GEOMAR and Kiel University organizes and supervises data storage and publication by marine science projects in a web-based multi-user system. In a first phase data are only available to the project user groups. After a three year proprietary time the data management team will publish these data by dissemination to national and international data archives, i.e. the data will be submitted to PANGAEA no later than July, 2017. Digital object identifiers (DOIs) are automatically assigned to data sets archived in the PANGAEA Open Access library making them publically retrievable, citeable and reusable for the future. All metadata are immediately available publically via the following link pointing at the GEOMAR portal (https://portal.geomar.de/metadata/leg/show/322819). In addition the portal provides a single downloadable KML formatted file which retrieves and combines up-to-date cruise (M107) related information, links to restricted data and to published data for visualisation e.g. in GoogleEarth.

The following data sets will become available: hydrological data from Glider, CTD casts, moorings, small sized satellite lander, and microstructure CTD; Meteor ADCP data, underway CTD measurements, underway biogeochemical data from a towed fish, water column biogeochemical, nutrient and trace metal data; water column and sediment radiotracer data from in situ pump, CTD casts and MUC deployments, porewater geochemistry from MUC and BIGO Lander; in situ flux measurements from BIGO Lander; benthic-pelagic microbiological data from MUC, BIGO Lander and from onboard incubations; data on viruses in the water column.

9 Acknowledgements

We thank Captain Michael Schneider, his officers and the crew of RV METEOR for their outstanding support. They created a very professional working environment and contributed a lot to the success of this cruise. The friendly atmosphere aboard is greatly acknowledged. We thank the Ministère des Peches et de l'Economie Maritime for its support and we would like to acknowledge the contribution of the German Ministry of Foreign Affairs (Wolfgang Mahrle). Many thanks are due to the Mauritanian observer Mamadou Ba (IMROP) who was very helpful and supportive. We would also like to express our gratitude to the Leitstelle METEOR/MERIAN for its valuable support. The ship time of RV METEOR was provided by the Deutsche Forschungsgemeinschaft. The collaborative research centre 754 "Climate – Biogeochemistry Interactions in the Tropical Ocean" is funded by the German Research Council, DFG.

10 References

Altschul, S.F., Gish, W., Miller, W., Myers, E.W., Lipman, D.J., 1990. Basic local alignment search tool. Journal of Molecular Biology 215, 403-410.

Beaton, A. D., Cardwell, C. L., Thomas, R. S., Sieben, V. J., Legiret, F., Waugh, E. M., Statham, P. J., Mowlem, M. C., and Morgan, H., 2012. Lab-on-Chip measurement of nitrate and nitrite for in situ analysis of natural waters. Environ. Sci. Technol. 46(17), 9548-9556.

Berg, P., Rysgaard, S., Funch, P., Sejr, M., 2001. Effects of bioturbation on solutes and solids in marine sediments. Aquatic Microbial Ecology 26, 81-94.

Bohlen, L., Dale, A. W., Sommer, S., Mosch, T., Hensen, C., Noffke, A., Scholz, F., Wallmann, K., 2011. Benthic nitrogen cycling traversing the Mauritanian oxygen minimum zone. Geochimica et Cosmochimica Acta 75, 6094-6111.

Boyd, P.W., and 30 others, 2000. Mesoscale iron fertilization elevates phytoplankton stocks in the polar Southern Ocean. Nature 407, 695-702.

Böckelmann, U., Szewzyk, U., Grohmann, E., 2003. A new enzymatic method for the detachment of particle associated soil bacteria. Journal of Microbiological Methods 55, 201-211.

Buesseler, K. O., Benitez-Nelson, C. R., Moran, S. B., Burd, A. B., Charette, M. A., Cochran, J. K., Coppola, L., Fisher, N. S., Fowler, S. W., Gardner, W., Guo, L. D., Gustafsson, O., Lamborg, C., Masque, P., Miquel, J. C., Passow, U., Santschi, P. H., Savoye, N., Stewart, G., and Trull, T., 2006. An assessment of particulate organic carbon to thorium-234 ratios in the ocean and their impact on the application of Th-234 as a POC flux proxy. Mar. Chem. 100, 213-233, 10.1016/j.marchem.2005.10.013.

Capone, D. G. 1993). Determination of nitrogenase activity in aquatic sampes using the acetylene reduction procedure. In P. F. Kemp, B. F. Sherr, E. B. Sherr, J. J. Coles (Eds.), Handbook of methods in aquatic microbial ecology (pp. 621–631). Boca Raton: CRC Press LLC.

Cassman, N., Prieto-Davó, A., Walsh, K., Silva, G.G.Z., Angly, F.E., Akhter, S., Barott, K., Busch, J., McDole, T., Haggerty, J.M., Willner, D., Alarcón, G., Ulloa, O., DeLong, E.F., Dutilh, B.E., Rohwer, F.L., Dinsdale, E.A., 2012. Oxygen minimum zones harbour novel viral communities with low diversity. Environmental Microbiology 14, 3043-3065.

Coale, K.H. et al., 2004. Southern Ocean Iron Fertilization Experiment: Carbon Cycling in High- and Low-Si Waters. Science 304(5669), 408-414.

Dale, A. W., Bertics, V. J., Treude, T., Sommer, S., Wallmann, K., 2013. Modeling benthic–pelagic nutrient exchange processes and porewater distributions in a seasonally hypoxic sediment: evidence for massive phosphate release by Beggiatoa? Biogeosciences 10, 629-651.

Dale, A. W., Sommer, S., Ryabenko, E., Noffke, A., Bohlen, L., Wallmann, K., Stolpovsky, K. , Greinert, J., Pfannkuche, O., 2014. Benthic nitrogen fluxes and fractionation of nitrate in the Mauritanian oxygen minimum zone (Eastern Tropical North Atlantic). Geochimica et Cosmochimica Acta 134, 234-256.

Dengler, M., Schafstall, J., Tanhua, T., Fiedler, B., Krahmann, G.,Löptin, U., eds . 2008 FS Poseidon Fahrtbericht / Cruise Report P347: Mauritanian Upwelling and Mixing Process Study, IFM-GEOMAR Report, 16 . IFM-GEOMAR, Kiel, 28 pp., DOI: 10.3289/ifm-geomar_rep_16_2008.

Grasshoff, K., Ehrhardt, M., Kremmling, K., 2009. Methods of Seawater Analysis, 632 pp., Wiley VCH, Weinheim, Germany

Hales, B., Hebert, D., Marra, J., 2009. Turbulent supply of nutrients to phytoplankton at the New England shelf break front, J. Geophys. Res. 114, C05010.

Hamersley, M.R., Turk, K.A., Leinweber, A., Gruber, N., Zehr, J.P., Gunderson, T., Capone, D.G., 2011 Nitrogen fixation within the water column associated with two hypoxic basins in the Southern California Bight. Aquatic Microbial Ecology 63: 193

Holtappels, M., Lavik, G., Jensen, M.M., Kuypers, M.M.M., 2011. ^{15}N-Labeling Experiments to Dissect the Contributions of Heterotrophic Denitrification and Anammox to Nitrogen Removal in the OMZ Waters of the Ocean. Methods in enzymology (1st ed., Vol. 486, pp. 223–251). Elsevier Inc. doi:10.1016/B978-0-12-381294-0.00006-7.

Ivanenkov, V.N., Lyakhin, Y.I., 1978, Determination of total alkalinity in seawater, in Methods of Hydrochemical Investigations in the Ocean, edited by O. K. Bordovsky and V. N. Ivanenkov, pp. 110–114, Nauka, Moscow.

John, S.G., Mendez, C.B., Deng, L., Poulos, B., Kauffman, A.K.M., Kern, S., Brum, J., Polz, M.F., Boyle, E.A., Sullivan, M.B., 2011. A simple and efficient method for concentration of ocean viruses by chemical flocculation. Environmental Microbiology Reports 3,195–202.

Jørgensen, B.B., 1978. A comparison of methods for the quantification of bacterial sulphate reduction in coastal marine sediments: I. Measurements with radiotracer techniques. Geomicrobiol. J. 1, 11-27.

Knauer, G.A., Martin, J.H., Bruland, K.W., 1979. Fluxes of particulate carbon, nitrogen, and phosphorus in the upper water column of the northeast Pacific. Deep-Sea Research 26, 97-108.

Ku, T.-L.,Luo, S., 2008. Ocean Circulation/Mixing Studies with Decay-Series Isotopes. In: S. Krishnaswami and J.K. Cochran (Editors), Radioactivity in the Environment. Elsevier, pp. 307-344.

Loescher, C.R., Groskopf, T., Desai, F.D., Gill, D., Schunck, H., Croot, P.L., Schlosser, C., Neulinger, S.C., Pinnow, N., Lavik, G., Kuypers, M.M.M., LaRoche, J., Schmitz, R.A., 2014, Facets of diazotrophy in the oxygen minimum zone waters off Peru. ISME J 8: 2180-2192.

Milne, A., Landing W., Bizimis, M., Morton, P., 2010. Determination of Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb in seawater using high resolution magnetic sector inductively coupled mass spectrometry (HR-ICP-MS). Analytica Chimica Acta 665(2), 200-207.

Mittelstaedt, E. 1983. The upwelling area off Northwest Africa – a description of phenomena related to coastal upwelling, Prog. Oceanogr., 12, 307–331, doi:10.1016/0079-6611(83)90012-5.

Pernthaler, A., Pernthaler, J., Amann, R., 2002. Fluorescence in situ hybridization and catalyzed reporter deposition for the identification of marine bacteria. Applied and Environmental Microbiology 68(6), 3094–101.

Rippeth, T.P., Wiles, P., Palmer, M.R., Sharples, J., Tweddle, J. 2009. The diapcynal nutrient flux and shear-induced diapcynal mixing in the seasonally stratified western Irish Sea, Continent. Shelf Res. 29, 13, 1580-1587.

Rutgers van der Loeff, M. M., Sarin, M. M., Baskaran, M., Benitez-Nelson, C. R., Buesseler, K. O., Charette, M. A., Dai, M., Gustafsson, O., Masque, P., Morris, P. J., Orlandini, K., Rodriguez y Baena, A. M., Savoye, N., Schmidt, S., Turnewitsch, R., Voge, I., Waples, J. T., 2006. A review of present techniques and methodological advances in analyzing Th-234 in aquatic systems, Mar. Chem. 100, 190-212.

Schafstall, J., Dengler, M., Brandt, P., Bange, H. 2010 Tidal induced mixing and diapycnal nutrient fluxes in the Mauritanian upwelling region, J. Geophys. Res., 115, C10014.

Sommer, S., P. Linke, O. Pfannkuche, T. Schleicher, J. Schneider v. Deimling, A. Reitz, M. Haeckel, S. Flögel, Hensen, C., 2009. Seabed methane emissions and the habitat of frenulate tubeworms on the Captain Arutyunov mud volcano (Gulf of Cadiz), Mar. Ecol. Prog. Ser., 382, 69–86, doi: 10.3354/meps07956.

Soutar, A., Kling, S.A., Crill, P.A., Duffrin, E., Bruland, K.W. 1977. Monitoring the marine environment through sedimentation. Nature 266, 136-139.

Stewart, W.D.P., Fitzgerald, G.P., Burris, R.H. 1967. In situ studies on N_2 fixation using the acetylene reduction technique. Proceedings of the National Academy of Sciences of the United States of America 58, 2071–2078.

Subramaniam, A., Mahaffey, C., Johns, W., Mahowald, N., 2013 Equatorial upwelling enhances nitrogen fixation in the Atlantic Ocean. Geophysical Research Letters 40: 1766-1771.

Tsuda, A. et al., 2003. A Mesoscale Iron Enrichment in the Western Subartic Pacific Induces a Large Centric Diatom Bloom. Science 300(5621), 958-961.

Vandieken, V., Nickel, M., Jørgensen, B.B., 2006. Carbon mineralization in Arctic sediments northeast of Svalbard: Mn(IV) and Fe(III) reduction as principal anaerobic respiratory pathways. Mar. Ecol. Prog. Ser. 322, 15-27.

White, A.E., Foster, R.A., Benitez-Nelson, C.R., Masqué, P., Verdeny, E., Popp, B.N., Arthur, K.E., Prahl, F.G., 2013 Nitrogen fixation in the Gulf of California and the Eastern Tropical North Pacific. Progress in Oceanography 109: 1-17.

Zhang, Z., Schwartz, S., Wagner, L., Miller, W., 2000. A greedy algorithm for aligning DNA sequences. Journal of Computational Biology 7, 203-214.

Appendix: Deployment and sampling details

Section 5.2.1

Table A1: Parameter for each glider deployed during the cruise

	Ifm02	Ifm03	Ifm07	Ifm12	Ifm13	Ifm14
Mission	Depl22	Depl11	Depl09	Depl04	Depl02	Depl01
Deployment date	19 June	09 June	10 June	13 June	12 June	20 June
Recovery date (2014)	30 June	27 June	30 June	13 August	27 June	30 June
Deployment period (days)	11	18	20	61	15	10
Sensors	p, T, S, chl-a, turbidity, oxygen	p, T, S, chl-a, turbidity, oxygen, CDOM	p, T, S, chl-a, turbidity, oxygen, CDOM	p, T, S, chl-a, turbidity, oxygen, CDOM	p, T, S, chl-a, turbidity, oxygen	p, T, S, chl-a, turbidity, oxygen, CDOM
Mounted sensors	Micro-structure	Micro-structure			Nitrate (Suna)	
max. depth (m)	200	300	190	1000	300	200

Table A2: Mooring operations

LR Mooring 18°N deployed / recoved
Vessel: Meteor cruise M107
Deployed: 10 June 2014 12:01
Vessel: Meteor cruise M107
Recovered: 26 June 2014 10:18
Latitude: 18° 12.208' N
Longitude: 016° 34.774' W
Water depth: 356 m
Mag Var: -6.80°

Notes: **KPO 1118**
Mooring was deployed at starboard side. Deployment and recovery went well.

ID	Depth	Instr. Type	s/n	Remarks:
KPO_1118_01	27	MicroCAT /p	6863	full record
KPO_1118_02	28	ADCP 75kHz LR down	7279	high-temporal resolution record until 24 June 21:46 (batteries were used up). Bins 8 and 9 are bad due to signal reflection from instruments below.
KPO_1118_03	74	MicroCAT	0284	full record
KPO_1118_04	75	Aquadopp DW down	5581	full record, screws at instrument head were loose after recovery
KPO_1118_05	126	MicroCAT	0929	full record
KPO_1118_06	177	MicroCAT /p	6862	full record
KPO_1118_07	222	MicroCAT	0933	full record
KPO_1118_08	223	Aquadopp DW down	6106	full record, screws at instrument head were loose after recovery
KPO_1118_09	274	MicroCAT	1319	full record
KPO_1118_10	336	MicroCAT	8947	full record
	350	Release AR861	107	code: B 495 455
	350	Release AR661	642	code: A 4A83 4A84

Double ADCP mooring 18°N deployed but <u>not recovered</u>.

Vessel: Meteor cruise M107

Deployed:	12 June	2014	14:17
Vessel:	Meteor cruise M107		
Recovered:			
Latitude:	18°	13.065' N	
Longitude:	016°	31.042' W	
Water depth:	164 m		
Mag Var:	-6.77°		

Notes: **KPO 1119** No signal from the releasers was received at mooring position during recovery attempt 14 days after deployment. Stress marks in the sediments observed with video-guided MUC suggested northward displacement. Search for the mooring (8h) was unsuccessful.

ID	Depth	Instr. Type	s/n	Remarks:
KPO_1118_01	132	ADCP 300kHz up	11436	not recovered
KPO_1118_02	132	ADCP 1200kHz up	7279	not recovered
	158	Release AR661	659	not recovered
	158	Release AR861	1255	not recovered

Double ADCP mooring (20°N) deployed and recovered

Vessel: Meteor cruise M107

Deployed:	16 June	2014	10:48
Vessel:	Meteor cruise M107		
Recovered:	30 June	2014	10:12
Dep. Latitude:	19°	54.810' N	
Dep. Longitude:	017°	33.005' W	
Dep. Water depth:		530 m	
Rec. Latitude:	19°	48.677' N	
Rec. Longitude:	017°	26.587' W	
Rec. Water depth:		1345 m	
Mag Var:	-6.93°		

Notes: **KPO 1121** Mooring was picked-up by the fishing net of a trawler on 19 June at 01:21 UTC and moved into deeper water. Top flotation was separated from the mooring by the trawler crew 2 hours later (cable was cut). Mooring was recovered on 30 June 8.6 nm southwest of the deployment position. Top flotation including WH-ADCP and Microcat were retrieved from Nouadhibou on 30 June where the instruments were left by the trawler crew.

ID	Depth	Instr. Type	s/n	Remarks:
KPO_1121_01	60	ADCP 300kHz up	1972	good until 19 June 01:20
KPO_1121_02	65	MicroCAT	6854	good until 19 June 01:20
KPO_1121_02	465	ADCP 75kHz LR up	2330	good until 19 June 01:20
	519	Release AR661	221	code:
	519	Release AR661	635	code:

Table A3: Oceanographic Lander operations

DOS Lander (18°N) deployed and recovered				**Notes:** **DOS**
Vessel: Meteor cruise M107				The DOS – Lander was deployed using W12 and a video-guided deployment frame on starboard side. Deployment and recovery went well.
Deployed:	14 June	2014	17:12	
Vessel:	Meteor cruise M107			
Recovered:	26 June	2014	16:19	
Latitude:	18°	13.992' N		
Longitude:	016°	26.980' W		
Water depth:	91.7 m			
Mag Var:	-6.74°			

ID	**Depth**	**Instr. Type**	**s/n**	**Remarks:**
	90	ADCP 300kHz up	1962	full record (2m bins, 1 - minute ensembles)

POZ Lander (18°N) deployed and recovered				**Notes:** **SLM1**
Vessel: Meteor cruise M107				The POZ – Lander was deployed using W12 and a video-guided deployment frame on starboard side. Deployment and recovery went well.
Deployed:	08 June	2014	17:22	
Vessel:	Meteor cruise M107			
Recovered:	27 June	2014	09:00	
Latitude:	18°	16.010' N		
Longitude:	016°	19.000' W		
Water depth:	55 m			
Mag Var:	-6.68°			

ID	**Depth**	**Instr. Type**	**s/n**	**Remarks:**
	54	ADCP 300kHz up	20027	full record (1m bins, 1 - minute ensembles)
	54	RBR (O_2, T, S, P, pH, Flouro)		full record

Section 5.3.2

Table A4: CTD Biogeochemical sampling

Lat (deg)	Long (deg)	Ship Station	CTD Profile	Sampled Depth (m)	Parameter
11°27.270'N	22°59.903'W	485	1	58, 250, 420, 650, 850, 1000	DOC, Bacteria, Phytoplankton, AA, Extracts
18°15.139'N	16°27.02'W	517	4	5, 10, 15, 20, 30, 40, 50, 65, 73, 83	DOC, Bacteria, Phytoplankton, AA, DOP
18°14.332'N	16°30.996'W	519	5	5, 10, 25, 41, 51, 60, 80, 109, 130, 154, 168	DOC, Bacteria, Phytoplankton, AA, DOP
18°13.088'N	16°33.310'W	521	6	10, 20, 30, 40, 50, 60, 80, 100, 130, 150, 170, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°12.519'N	16°35.722'W	523	7	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 160, 180, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°2.004'N	17°10.031'W	531	8	10, 15, 20, 25, 30, 35, 40, 50, 100, 140, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°4.989'N	17°0.010'W	533	9	10, 15, 20, 25, 30, 35, 40, 50, 75, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°07.011'N	16°52.571'W	549	14	10, 67, 100, 150, 200, 300, 400, 500, 600	DOC, Bacteria, Phytoplankton, AA, DOP
18°13.998'N	16°31.003'W	560	17	5, 10, 15, 20, 30, 40, 50, 60, 80, 100, 130, 157	DOC, Bacteria, Phytoplankton, AA, DOP
18°14.700'N	16°32.554'W	565	18	5, 10, 15, 20, 30, 40, 50, 60, 80, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°13.016'N	16°33.268'W	568	19	10, 20, 30, 40, 50, 60, 80, 100, 120, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°17.289'N	16°18.915'W	574	20	5, 10, 15, 20, 25, 30, 40	DOC, Bacteria, Phytoplankton, AA, DOP
18°10.343'N	16°43.020'W	576	21	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 80, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°13.604'N	16°31.759'W	578	22	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 80, 100, 150, 180	DOC, Bacteria, Phytoplankton, AA, DOP
18°12.325'N	16°36.068'W	579	23	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 80, 100	DOC, Bacteria, AA, DOP
18°10.877'N	16°41.588'W	586	25	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 80, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°10.877'N	16°41.588'W	587	26	10, 25, 40, 60	DOC, Bacteria, Phytoplankton, AA, DOP
18°13.000'N	16°37.952'W	589	27	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°12.583'N	16°35.585'W	592	28	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°13.590'N	16°31.746'W	594	29	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 70, 60, 100, 150	DOC, Bacteria, Phytoplankton, AA, DOP
19°54.018'N	17°33.266'W	601	31	5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 80, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°11.245'N	16°39.323'W	605	32	5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 80, 100, 125, 150, 175, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°12.473'N	16°35.593'W	609	33	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 80, 100, 150, 200, 275, 350	DOC, Bacteria, Phytoplankton, AA, DOP

18°13.002'N	16°33.287'W	611	34	5, 10, 20, 30, 35, 40, 45, 50, 60, 80, 100, 150, 200	DOC, Bacteria, AA, DOP
18°14.185'N	16°30.998'W	618	36	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 80, 100, 120, 150	DOC, Bacteria, Phytoplankton, AA, DOP
18°14.870'N	16°28.790'W	623	37	5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 75, 100	DOC, Bacteria, Phytoplankton, AA, DOP
18°15.194'N	16°26.982'W	625	38	5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80	DOC, Bacteria, Phytoplankton, AA, DOP
18°11.284'N	16°39.289'W	634	41	(10), 20, (30), (40), 50, 60, (70), 80, 100, (160), (200), (350), (700)	DOC, Bacteria, Phytoplankton, AA, DOP, (TEP)
18°09.909'N	16°45.040'W	637	42	(10), 20, (30), (40), 50, 60, 70, (80), 100, (150), 200, (350), (600), (1000)	DOC, Bacteria, Phytoplankton, AA, DOP, (TEP)
18°14.094'N	16°31.223'W	641	44	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 80, 60, 100, 120, 150	DOC, Bacteria, Phytoplankton, AA, DOP
18°17.233'N	16°18.964'W	650	48	5, 10, 15, 20, 25, 30, 35, 40	DOC, Bacteria, Phytoplankton, AA, DOP
18°15.189'N	16°27.007'W	651	49	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 80	DOC, Bacteria, Phytoplankton, AA, DOP
18°15.983'N	16°24.100'W	655	50	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60	DOC, Bacteria, Phytoplankton, AA, DOP
18°16.690'N	16°21.493'W	657	51	5, 10, 15, 20, 25, 30, 35, 40, 45, 50	DOC, Bacteria, Phytoplankton, AA, DOP
18°0.008'N	17°16.997'W	667	53	5, (10), 15, 20, 25, (30), 35, (40), 45, (50), 60, 80, 100, (150), 200, (430), (600), (1000), 1400, 2100	DOC, Bacteria, Phytoplankton, AA, DOP, (TEP)
18°13.094'N	16°33.298'W	675	55	5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 80, 100, 115, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°12.493'N	16°35.596'W	680	57	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 80, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°14.296'N	16°31.016'W	682	58	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60,80, 100, 150	DOC, Bacteria, Phytoplankton, AA, DOP
18°12.482'N	16°35.574'W	689	59	5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 80, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
18°14.791'N	16°28.573'W	693		5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 80, 90	DOC, Bacteria, Phytoplankton, AA, DOP
18°13.670'N	16°32.007'W	705	63	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 80, 100, 150	DOC, Bacteria, Phytoplankton, AA, DOP
18°9.990'N	16°44.972'W	709	64	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 100, 150, 200, 400, 600, 800, 1000	DOC, Bacteria, AA
19°53.684'N	17°33.846'W	719	66	5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 80, 100, 150, 200	DOC, Bacteria, Phytoplankton, AA, DOP
19°38.988'N	17°42.002'W	723	67	10, 15, 20, 25, 30, 35, 40, 75, 50, 100, 150, 200	DOC, Bacteria, AA
19°42.561'N	17°38.321'W	725	69	10, 15, 20, 25, 30, 35, 40, 50, 75, 100, 150, 200	DOC, Bacteria, AA
19°46.079'N	17°34.578'W	727	71	10, 15, 20, 25, 30, 35, 40, 50, 75, 100, 150, 200	DOC, Bacteria, AA
19°49.73'N	17°30.84'W	728	72	10, 15, 20, 25, 30, 35, 40, 50, 75, 100, 150, 200	DOC, Bacteria, AA
19°53.32'N	17°27.10'W	729	73	10, 15, 20, 25, 30, 35, 40, 50, 75, 100, 150, 200	DOC, Bacteria, AA

Section 5.3.4

Table A5: Positions of the surface seawater samples collected during the transit from Fortaleza to the Mauritanian upwelling area. Collected samples are indicated (x).

Fish#	Date	Time (UTC)	Lat	Long	DFe	TDFe	Nuts	Incub.	CDOM/FDOM	Extracts
1	01/06/2014	19:55	-0.315	-61.449	X	X	X		X	X
2	01/06/2014	21:09	-0.038	-61.175	X		X			
3	02/06/2014	00:00	0.610	-60.535	X	X	X		X	X
4	02/06/2014	02:49	1.254	-59.908	X		X			
5	02/06/2014	06:00	1.983	-59.188	X	X	X			
6	02/06/2014	08:00	2.438	-58.738	X		X	X		
7	02/06/2014	11:00	3.121	-58.064	X	X	X		X	X
8	02/06/2014	14:03	3.836	-57.357	X		X		X	X
9	02/06/2014	17:15	4.573	-56.629	X	X	X			
10	02/06/2014	18:01	4.745	-56.459					X	X
10b	02/06/2014	20:10	5.220	-55.989	X		X			
11	02/06/2014	21:30	5.510	-55.701	X	X	X	X		
12	02/06/2014	22:53	5.818	-55.398	X		X		X	X
13	03/06/2014	01:57	6.493	-54.730	X	X	X			
14	03/06/2014	11:00	8.467	-52.691	X	X	X		X	X
14b	03/06/2014	12:00	8.679	-52.463			X	X		
15	03/06/2014	14:00	9.085	-52.026	X	X	X			
16	03/06/2014	16:00	9.533	-51.545					X	X
17	03/06/2014	17:00	9.756	-51.304	X		X			
18	03/06/2014	20:05	10.415	-50.595	X	X	X		X	X
19	03/06/2014	22:00	10.821	-50.158					X	X
19b	04/06/2014	01:55	11.636	-49.280	X		X			
20	04/06/2014	05:00	12.251	-48.617	X	X	X			
21	04/06/2014	08:00	12.832	-47.990	X	X	X	X		
22	04/06/2014	11:00	13.404	-47.372	X	X	X		X	X
23	04/06/2014	14:10	14.016	-46.710	X		X			
24	04/06/2014	17:00	14.580	-46.101	X	X	X		X	X
25	04/06/2014	20:00	15.188	-45.441	X		X			
26	04/06/2014	23:00	15.773	-44.824	X	X	X		X	X
27	05/06/2014	02:00	16.360	-44.171	X		X			
28	05/06/2014	05:00	16.954	-43.525	X	X	X			
29	05/06/2014	07:00	17.351	-43.094	X		X	X		
30	05/06/2014	10:00	17.962	-42.430	X		X			
31	05/06/2014	11:00	18.166	-42.208					X	X

32	**05/06/2014**	**13:00**	**18.571**	**-41.767**	**X**	**X**	**X**
33	**05/06/2014**	**18:15**	**19.635**	**-40.606**	**X**	**X**	**X**
34	**05/06/2014**	**19:20**	**19.862**	**-40.358**	**X**	**X**	**X**
35	**05/06/2014**	**20:00**	**19.963**	**-40.180**	**X**	**X**	

Table A6: Deployments (casts) of the Trace Metal CTD. Based on operational problems, at two stations two identical casts were conducted after each other. Collected samples are indicated (x).

Cast/ station no.	Date	Time UTC	Laitude	Longitude	Water Depth	Sample Depth	DFe	TDFe	SFe	Iodide
Cast 1 (539-1)	**10.06.2014**	**21:21**	**18,19N**	**16,651 W**	**762 m**	**~ 500 m**	**X**	**X**	**X**	**X**
						~ 600 m	**X**	**X**	**X**	**X**
						~ 700 m	**X**	**X**	**X**	**X**
						botom	**X**	**X**	**X**	**X**
Cast 2 (553-1)	**12.06.2014**	**05:07**	**18,15N**	**16,751 W**	**1136 m**	**~ 30 m**	**X**	**X**		**X**
						~ 50 m	**X**	**X**		**X**
						~ 90 m	**X**	**X**		**X**
						~ 200 m	**X**	**X**		**X**
						~ 280 m	**X**	**X**		**X**
						~ 350 m	**X**	**X**		**X**
						~ 450 m	**X**	**X**		**X**
						~ 550 m	**X**	**X**		**X**
						~ 700 m	**X**	**X**		**X**
						~ 850 m	**X**	**X**		**X**
Cast 3 (562-2)	**12.06.2014**	**21:15**	**18,23N**	**16,517 W**	**167 m**	**~ 13 m**	**X**	**X**		**X**
Cast 3 (562-1)	**12.06.2014**	**20:36**	**18,23N**	**16,516 W**	**165 m**	**~ 25 m**	**X**	**X**		**X**
						~ 40 m	**X**	**X**		**X**
						~ 60 m	**X**	**X**		**X**
						~ 80 m	**X**	**X**		**X**
						~ 100 m	**X**	**X**		**X**
						~ 125 m	**X**	**X**		**X**
						bottom	**X**	**X**		**X**
Cast 4 (575-1)	**13.06.2014**	**20:40**	**18,29N**	**16,315 W**	**46 m**	**~ 6 m**	**X**	**X**	**X**	**X**
						~ 13 m	**X**	**X**	**X**	**X**

						~ 25 m	**X**	**X**	**X**	**X**
						~ 35 m	**X**	**X**	**X**	**X**
						bottom	**X**	**X**	**X**	**X**
Cast 5 (606-1)	**19.06.2014**	**23:24**	**18,19N**	**16,655 W**	**795 m**	**~ 6 m**	**X**	**X**	**X**	**X**
						~ 15 m	**X**	**X**	**X**	**X**
						~ 30 m	**X**	**X**	**X**	**X**
						~ 50 m	**X**	**X**	**X**	**X**
						~ 75 m	**X**	**X**	**X**	**X**
						~ 100 m	**X**	**X**	**X**	**X**
						~ 150 m	**X**	**X**	**X**	**X**
						~ 200 m	**X**	**X**	**X**	**X**
						~ 250 m	**X**	**X**	**X**	**X**
						~ 350 m	**X**	**X**	**X**	**X**
						~ 450 m	**X**	**X**	**X**	**X**
Cast 6 (620-1)	**20.06.2014**	**17:59**	**18,24N**	**16,518 W**	**173 m**	**~ 13 m**	**X**	**X**	**X**	**X**
Cast 6 (619-1)	**20.06.2014**	**17:34**	**18,24N**	**16,517 W**	**173 m**	**~ 25 m**	**X**	**X**	**X**	**X**
						~ 40 m	**X**	**X**	**X**	**X**
						~ 60 m	**X**	**X**	**X**	**X**
						~ 80 m	**X**	**X**	**X**	**X**
						~ 100 m	**X**	**X**	**X**	**X**
						~ 125 m	**X**	**X**	**X**	**X**
						bottom	**X**	**X**	**X**	**X**
Cast 7 (652-1)	**22.06.2014**	**23:19**	**18,25N**	**16,450 W**	**91 m**	**~ 10 m**	**X**	**X**	**X**	**X**
						~ 20 m	**X**	**X**	**X**	**X**
						~ 30 m	**X**	**X**	**X**	**X**
						~ 40 m	**X**	**X**	**X**	**X**
						~ 50 m	**X**	**X**	**X**	**X**
						~ 60 m	**X**	**X**	**X**	**X**
						~ 70 m	**X**	**X**	**X**	**X**
						~ 80 m	**X**	**X**	**X**	**X**
Cast 8 (676-1)	**24.06.2014**	**22:22**	**18,22N**	**16,555 W**	**238 m**	**~ 10 m**	**X**	**X**	**X**	**X**
						~ 25 m	**X**	**X**	**X**	**X**
						~ 50 m	**X**	**X**	**X**	**X**
						~ 75 m	**X**	**X**	**X**	**X**
						~ 100 m	**X**	**X**	**X**	**X**
						~ 125 m	**X**	**X**		**X**

						~ 150 m	**X**	**X**	**X**	**X**
						~ 175 m	**X**	**X**		**X**
						~ 200 m	**X**	**X**		**X**
						~ 230 m	**X**	**X**	**X**	**X**
Cast 9 (690-1)	**25.06.2014**	**21:10**	**18,21N**	**16,593 W**	**413 m**	**~ 25 m**	**X**	**X**	**X**	**X**
						~ 50 m	**X**	**X**	**X**	**X**
						~ 100 m	**X**	**X**	**X**	**X**
						~ 125 m	**X**	**X**	**X**	**X**
						~ 150 m	**X**	**X**	**X**	**X**
						~ 175 m	**X**	**X**	**X**	**X**
						~ 200 m	**X**	**X**	**X**	**X**
						~ 250 m	**X**	**X**	**X**	**X**
						~ 300 m	**X**	**X**	**X**	**X**
						~ 350 m	**X**	**X**	**X**	**X**
						~ 400 m	**X**	**X**	**X**	**X**
Cast 10 (706-1)	**26.06.2014**	**22:49**	**18,23N**	**16,553 W**	**189 m**	**~ 20 m**	**X**	**X**	**X**	**X**
						~ 40 m	**X**	**X**	**X**	**X**
						~ 60 m	**X**	**X**	**X**	**X**
						~ 80 m	**X**	**X**	**X**	**X**
						~ 100 m	**X**	**X**	**X**	**X**
						~ 120 m	**X**	**X**	**X**	**X**
						~ 140 m	**X**	**X**	**X**	**X**
						~ 155 m	**X**	**X**	**X**	**X**

Section 5.3.8

Table A7: Deployments of the LOC for nitrite and nitrite measurements

Date	METEOR Station No	Operation	Depth, m	Sensor Start UTC	Sensor End UTC
08.06.2014	M107-516	CTD/RO #3	50	08.06.2014 18:28	08.06.2014 20:52
12.06.2014	M107-559	CTD/RO #16	174	12.06.2014 15:00	12.06.2014 17:10
13.06.2014	M107-572	Profiler #1	174	13.06.2014 16:00	14.06.2014 14:00
21.06.2014	M107-633	Profiler #2	100	21.06.2014 15:00	23.06.2014 07:00
25.06.2014	M107-687	Profiler #3	50	25.06.2014 15:00	26.06.2014 23:00

Section 5.4.1

Table A8: Stations, porewater sampling method and number of samples measured in multiple corers (MUC) and benthic landers (BIGO).

Station	method	Water depth (m)	Date (2014)	Lat. [°N]	Long. [°W]	No. samples
524 MUC 1	glove bag	1108	09-Jun	18°09.991'	16°45.023'	23 [a]
527 BIGO 2-1	press	1096	09-Jun	18°10'	16°44.99'	13
534 MUC 3	glove bag	786	10-Jun	18°11.288'	16°39.328'	22 [a]
547 BIGO 1-1	press	787	11-Jun	18°11.31'	16°39.335'	13
554 MUC 5	glove bag	412	12-Jun	18°12.505'	16.35.584'	18
555 MUC 6	press	412	12-Jun	18°12.505'	16°35.583'	0 [b]
557 BIGO 2-2	press	412	12-Jun	18°12.504'	15°35.585'	13
583 MUC 7	press	237	14-Jun	18°12.998'	16°33.197'	0 [b]
598 BIGO 1-2	press	236	15-Jun	18°13.286'	16°33.334'	12
612 MUC 8	rhizones	236	20-Jun	18°12.945'	16°33.153'	15
617 BIGO 2-3	press	171	20-Jun	18°14.397'	16°31.000'	13
628 MUC 10	rhizones	91	21-Jun	18°15.197'	16°27.002'	11 [a]
630 BIGO 1-3	press	91	21-Jun	18°15.006'	16°27.010'	11
658 MUC 13	rhizones	46	23-Jun	18°17.299'	16°18.994'	15 [a]
659 MUC 14	rhizones	46	23-Jun	18°17.299'	16°18.994'	0 [b]
665 BIGO 2-4	press	47	23-Jun	18°17.100'	16°18.997'	10
669 MUC 15	press	1099	24-Jun	18°10.001'	16°44.997'	18
672 MUC 17	rhizones	130	24-Jun	18°14.483'	16°29.634'	16
673 BIGO 1-4	press	131	24-Jun	18°14.485'	16°29.635'	0 [b]
686 MUC 19	rhizones	65	25-Jun	18°16.287'	16°22.910'	17
688 BIGO 2-5	press	65	25-Jun	18°16.286'	16°22.932'	11
697 MUC 20	glove bag	169	26-Jun	18°14.299'	16°30.995'	18 [a]

[a] Parallel MUC cores were taken for bioirrigation/bioturbation experiments. Analyses of these samples will be done at GEOMAR.

[b] These cores were used for bioirrigation/bioturbation experiments only.

Section 5.4.3

Table A9: Sediment sampling details: nitrogen fixation (N-fix = nitrogenase activity determined via acetylene reduction; ^{15}N-Fix = $^{15}N_2$-labelling method), ammonium uptake ($^{15}NH_4$-Fix), nitrogen fixation exposed to different ammonium concentrations (N-fix+NH4), sulfate reduction, iron reduction, CARD-FISH/ RNA/DNA analyses, and chlorophyll .

Stat.	Gear	N-fix	^{15}N-Fix	$^{15}NH_4$-Fix	N-fix + NH_4	Sulfate reduct.	Iron reduct.	CARD-FISH/ RNA/DNA	Chlorophyll
524	MUC-1	X				X	X	X	X
527	BIGO 2-1	X				X		X	
534	MUC-3	X				X	X	X	X
547	BIGO I-1	X				X		X	
554	MUC-5	X				X	X	X	X
555	MUC-6								
557	BIGO II-2	X				X		X	
598	BIGO I-2	X				X		X	
612	MUC 8	X				X		X	
613	MUC 9						X		X
617	BIGO II-3	X				X		X	
628	MUC 10	X				X		X	
629	MUC 11						X		X
630	BIGO I-3	X				X		X	
658	MUC 13	X				X	X	X	X
659	MUC 14				X				
665	BIGO II-4	X				X		X	
669	MUC 15								
685	MUC 18		X	X					
699	MUC 21		X	X	X				

Section 5.4.3

Table A10: Sampling location for the experiments at 237 and 46 m water depth, sampling method, and number of samples (water samples, porewater, solid phase) obtained during the time course of the experiment.

<table>
<tr><th>Station</th><th>Latitude [N]</th><th>Longitude [W]</th><th>Water depth [m]</th><th>Exp. series</th><th>Core</th><th>Method</th><th>No. samples</th></tr>
<tr><td rowspan="6">583MUC7</td><td rowspan="6">18°12.998'</td><td rowspan="6">16°33.197'</td><td rowspan="6">237</td><td rowspan="6">I</td><td rowspan="2">A</td><td>Bottom water sampling</td><td>66</td></tr>
<tr><td>Pore water &solid phase sampling</td><td>19</td></tr>
<tr><td rowspan="2">B</td><td>Bottom water sampling</td><td>84</td></tr>
<tr><td>Pore water &solid phase sampling</td><td>18</td></tr>
<tr><td rowspan="2">C</td><td>Bottom water sampling</td><td>84</td></tr>
<tr><td>Pore water &solid phase sampling</td><td>16</td></tr>
<tr><td rowspan="3">647MUC12</td><td rowspan="3">18°17.297'</td><td rowspan="3">16°19.000'</td><td rowspan="3">46</td><td rowspan="3">II</td><td>A</td><td>Bottom water sampling</td><td>26</td></tr>
<tr><td>B</td><td>Bottom water sampling</td><td>26</td></tr>
<tr><td>C</td><td>Bottom water sampling</td><td>26</td></tr>
</table>

Remarks: Experiment II was stopped after 4 days due to leaking cores caused by small stones lodged between the bottom stopper and core liner.