Short Cruise Report
RV Meteor Cruise M57-3

Dates: 15 March to 15 April

Port calls: Walvis Bay (Namibia) – Dakar (Senegal)

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Summary of cruise

The Namibian shelf between 22°S and 25°S is characterized by nearly continuous upwelling, high primary production, extreme water column oxygen depletion, and episodic sulfidic bottom waters (Bailey et al., 2001; Boyd, 1983). Observations made during Meteor expedition M48-2 suggested a close relationship between anoxia and episodically recurring eruptions of biogenic methane that is formed by the intense bacterial degradation processes in the sediment (Emeis et al., 2001). The gas accumulations in the unconsolidated sediments may be released following changes in the physical regime of the overlying water or the sediment. The widespread shelf anoxia has significant implications for biogeochemical fluxes between sediment and bottom water and for the living resources (fish and crustaceans) in one of the largest marine ecosystems on earth.

The specific objectives of METEOR expedition 57-3 were:

- To continue the hydrographic studies started during Meteor expedition M 57-2 on the transect at 23°S to record the variation in coastal upwelling, current strength and direction, water mass composition, and oxygen and nutrient contents. Secondly, to recover a mooring at 23°S, 14°E, 130 m water depth that was deployed in December 2002 to record variations in current strength and direction, as well as temperature, salinity and oxygen concentrations.

- To deploy a CTD equipped with a pumping system for continuous profiling of nutrients and dissolved sulfide in the water column. The high-resolution profiling of the nutrients phosphate, ammonium, nitrite, and nitrate was the basis for studying key microbial processes of the nitrogen cycle in different layers of the water column.

- To analyze the structure and function of the bacterioplankton community in the water column using flow cytometry, radioactive labeling, and fluorescence imaging.

- To run an acoustic survey across the shelf between 22°S and 23°30‘S to map the distribution of free gas in the sediment and to detect, if possible, potential outbreak areas of hydrogen sulphide and methane.

- To recover short and long cores from areas potentially affected by gas eruptions and from undisturbed reference areas for measurement of methane, total inorganic carbon, ammonium, and dissolved sulfide concentrations.

- To analyze the spectral properties of the water column for validation of satellite data and to use daily true color satellite images to identify, if possible, plumes of elemental sulfur indicative of hydrogen sulfide-laden gas eruptions.

- To recover sediment cores for paleoceanographic reconstruction of low-O_2 and anoxic environments using specific dinoflagellate cysts and stable isotopes as proxies, furthermore to collect material from the sediment surface for high-resolution profiling of oxygen, sulfide, and pH and for labeling experiments of the large sulfur bacteria to study their role in the benthic nitrogen and sulfur cycles.

- To collect and quantify live species of the benthic foraminifer Virgulinella, a characteristic benthic species for low-O_2 and anoxic bottom waters.

- To filter and collect particulate matter from the water column for microscopic, elemental, and stable isotopic analysis.

R/V Meteor left Walvis Bay on March 15 at 9:00 LT and set out for the first station which was occupied only 2 hours later (Figure 1: Overview map of sampling stations and acoustic profiles). The first task was the scheduled repetition of the CTD transect at 23°S. A modification of the operation included the deployment of the IOW-owned pump-CTD system for continuous water column profiling of nutrients. It soon became clear that the bottom water oxygen concentrations on the shelf were very low or below detection, but that the bottom waters were not sulfidic. This condition persisted for the length of the cruise. Selected stations along the transit were used to obtain surface sediment from the multicorer. We encountered initial difficulties in sampling the extremely watery sediments into which the multicorer sank without triggering although we made it more buoyant by the use of 6 triangular bases as feet. The situation improved on the outer shelf and slope where the sediment was harder and where we could recover excellent surface samples. After some maintenance, the heavily used multicorer also worked without a problem even in the very soft, shallow-water sediment.

After completion of the first transect, we headed back to the shelf and started our extensive sampling program. While on station and in transit between stations, our operation was accompanied by continuous surveying with Parasound, Hydrosweep and the Uni Rostock-developed sediment echosounder SEL 96, specifically designed for high-resolution profiling of the near-surface sediment. In general, the station program started with deployment of the CTD Rosette or the pump CTD Rosette system. Next came the plankton net, in-situ pumps and, when we had daylight, we recorded water color, Secchi depth, and measured absorption and spectral properties of surface water. The latter served for validation of satellite-based remote sensing data. Whenever possible, we timed the spectral measurements with the over-passing of the SEAWIFS and the MERIS satellites. Surface sediment samples were taken with a small van Veen grab sampler for sieving the coarse fraction, e.g., fish remains, and with a multicorer to obtain an intact sediment-water interface.

The demand for intact sediment surface samples was very high. At one station, 70 core tubes were requested. This material was used by the geologists, paleontologists, the microbiologists, and the biogeochemists for determination of physical properties, counting of benthic forams and of dinoflagellates and their cysts, for microbial rate measurements and for chemical profiling. Processing of the cores took place right after retrieval on deck. A strong H_2S smell of all cores accompanied us throughout the cruise. In addition to the multicore samples, we recovered gravity cores (6 m and 12 m) at selected stations. After sufficient sediment material had been obtained for the different working groups to last for 3 to 4 days lab work, we started the first half of a Parasound/SEL 96 grid to map the gas distribution in the diatomaceous mud belt, which covered an area from 60 m to approximately 150 m water depth from Walvis Bay to Sandwich Harbour. In this area, we found abundant evidence for disturbance of the sediment surface and high concentrations of free gas only centimeters below the sediment water interface. The most conspicuous of these structures was a 10-m deep crater with a structure similar to pockmarks reported in the Baltic and Barents Sea. We selected 4 of these structures to investigate the composition of the water column in high resolution using the pump-CTD system and by deploying in-situ pumps at the oxycline and throughout the anoxic part of the water column. In addition, we employed the Mariscope ROV of the GeoBio Center at the Ludwig Maximilian University Munich. However, due to the strong current, it was not possible to steer the ROV. After some experimentation, we decided to hook the ROV to the winch rope. With running movie camera, we obtained an impressive short movie showing the enormous organic particle density in the water column of this coastal upwelling system. Despite the heaving of the ship, the camera also gave clear images of a cratered sea floor occupied by mats tentatively identified as *Beggiatoa* spp. Even more impressively, small gas bubbles could be observed rising to the surface. Bottom contact of the ROV triggered small gas eruptions. The sediment was so saturated with gas that big bubbles rose from the multicores when on deck. In addition, we recovered a long gravity core from this station, which to our surprise was only sulfidic and gas-rich in the upper 2 meters but had a strong bituminous smell below. A similar program to the one run at the crater station was repeated two more times including a control station where the acoustic surveying indicated that free gas was located deeper and where the sediment surface appeared to be undisturbed.

Following the work on the 2nd transect, we resumed the acoustic mapping with Parasound and SEL 96, this time starting north at Cape Cross and working our way south towards Walvis Bay. Next, we worked on four sediment stations in shallow water that are regularly visited as part of a long-term biogeochemical study on the role of hydrogen sulfide production and consumption in the sediment on the Namibian shelf by members of the Namibian Fisheries Institute in collaboration with the MPI Bremen. At one of the stations, the acoustic profiling indicated shallow-dipping reflectors less than 3 meters below the sediment surface. Previously, all efforts to penetrate into these reflective layers had failed because of a basal conglomerate and shell layer on top of them. We chose to deploy the somewhat cumbersome vibrocorer of the IOW. The effort was successful, and it took the vibrocorer only two minutes to penetrate the basal conglomerate and to recover an intact 6 m long core that reached into the coastal sand and gravel below the diatomaceous mud. The next day we selected an additional site with shallow reflectors and were again successful.

In the days following March 29, we recognized on the SEAWIFS satellite images the development of a turquoise water mass some 50 km long and 10 – 15 km wide. This conspicuous discoloration was similar to discolorations caused by the hydrogen sulfide events that occur along the Namibian coast. We estimated that sufficient time was left to detour to the plume to sample the surface waters and run two CTD profiles. To our surprise, the waters were occupied by abundant blue green algae, i.e., potentially N_2-fixing cyanobacteria, organisms that appear to be somewhat out of place in this nutrient-rich upwelling environment. Subsequently, we completed the third transect after this detour and returned to the coast to recover a CTD/ADCP-equipped benthic mooring deployed in December by the IOW. The mooring was recovered and found intact having continuously recorded data on current strength and oxygen contents for the past 4 months.

After this last work task on the Namibian shelf, we started our transit to Dakar. After transferring our Namibian guest scientists to the RV Dr. Fridtjof Nansen near the Angolan border, we then changed course direction Dakar and headed northwest towards the equator. Once outside the 200-Mile commercial zone, we resumed recording with ADCP, Parasound and thermosalinograph in addition to regular daily sampling of dust particles on the pilot deck. Since the course of the ship was presumed to cross the outflow of the Kongo river, there appeared to be an opportunity to sample these waters as well. Appropriate timing of sampling with the overpassing of the MERIS and SEAWIFS satellites allowed us to validate satellite algorithms for the calculation of chlorophyll-a concentrations. Abundant cyanobacteria occupied the waters of the central gyre providing an opportunity for additional N_2-fixation rate measurements. The last station of the cruise was occupied 8 April at 15:00 LT on the equator.

In the final days of our transit to Dakar, equipment was packed and prepared for shipment back to Dakar. Having arrived safely in the morning of 13 April and after customs and immigration clearance, the expedition ended 13 April at 9:00.

Figure 1. Map of M57-3 cruise trackplot