5.4 Marine Geoscience M41/4

5.4.1 CTD-O_2-Chlorophyll-Fluorescence Probe

(V. Ratmeyer)

Nine CTD/O_2/Chl-a profiles were taken with a self-contained SBE 19 profiler equipped with a conductivity-temperature-depth probe plus oxygen sensor and a CHELSEA-fluorometer. All sensors were calibrated prior to the cruise by the manufacturer. The calibration coefficients from this calibration have been used to process the down-cast data on board shortly after data retrieval However, during most casts the oxygene values seem to be too high, with a positive drift of about 2 mg/l. Using a sampling rate of 2 samples/dbar, the CTD was deployed 70 m to 100 m above the bottom reaching multicorer, 20 to 50 m above the GoFlo-sampler, and 10 m above the ParCa II video system. Profiles with the CTD were taken between 1500 and 5500 m depth. The raw data were recovered on board and downcast standard plots were immediately produced to evaluate the stratification of the water column at all sampling sites. Four profiles are shown and described below as examples (Figure 120a-d).

At the Cape Blanc site (Station GeoB 5210-7; Figure 120a), a well mixed upper layer down to 120 m water depth causes low temperature and oxygen gradient at these depths. Chlorophyll concentrations are revealed from the CHELSEA fluorescence probe and show highest values up to 0.18 mg/l in the upper 80-100 m. Around 300 and 500 m, two 0.02 mg/l Chl-peaks appeared. A distinct oxygen minimum with values around 3 mg/l was observed between 500 m and 650 m water depth. Between 600 and 1000 m, a salinity minimum shows the almost northernmost influence of the AAIW. The NADW is found below 1600 m water depth, characterized by oxygen values around 6.5 mg/l and temperatures below 4°C.

The profile taken at the Cape Verde site (CV, GeoB 5209-6, Figure 120b) shows a well developed mixed surface layer down to about 50 m waterdepth. The main thermocline is found below 80 m water depth where the highest chlorophyll concentrations occur (0.19 mg/l). Just below the thermocline around 100 m, an oxygen minimum of < 2 mg/l was observed. A deeper oxygen minimum with values around 1.2 mg/l is located between 400 and 500 m water depth, concurrent with a chlorophyll maximum at 400 m with values around 0.03 mg/l. Relatively high Chl-values > 0.02 mg/l are found down to 1000 m water depth. Below 1600 m water depth, the North Atlantic Deep Water (NADW) can be found.

Around 10°W in the eastern equatorial upwelling area, a series of profiles from 2°N to 2°S shows the clear stratification of the water column with a distinct AAIW-signal between 500 and 1000 m depth. Surface chlorophyll values are highest on the equatorial site (GeoB 5206-2), however all sites show the same range of Chl-values between 0.03 and 0.01 mg/l between 200 and 1100 m depth. A distinct deep maximum could be found between 200 and 500 m depth at the southern site GeoB 5205-10 (Figure 120c).

The western equatorial sites show a clearly deeper Chl-maximum and thermocline depth around 80 to 120 m compared to the eastern stations. In addition to the watermasses found in the eastern sites, the AABW was found below 4000 m depth, characterized by temperatures below 4° C.

a.

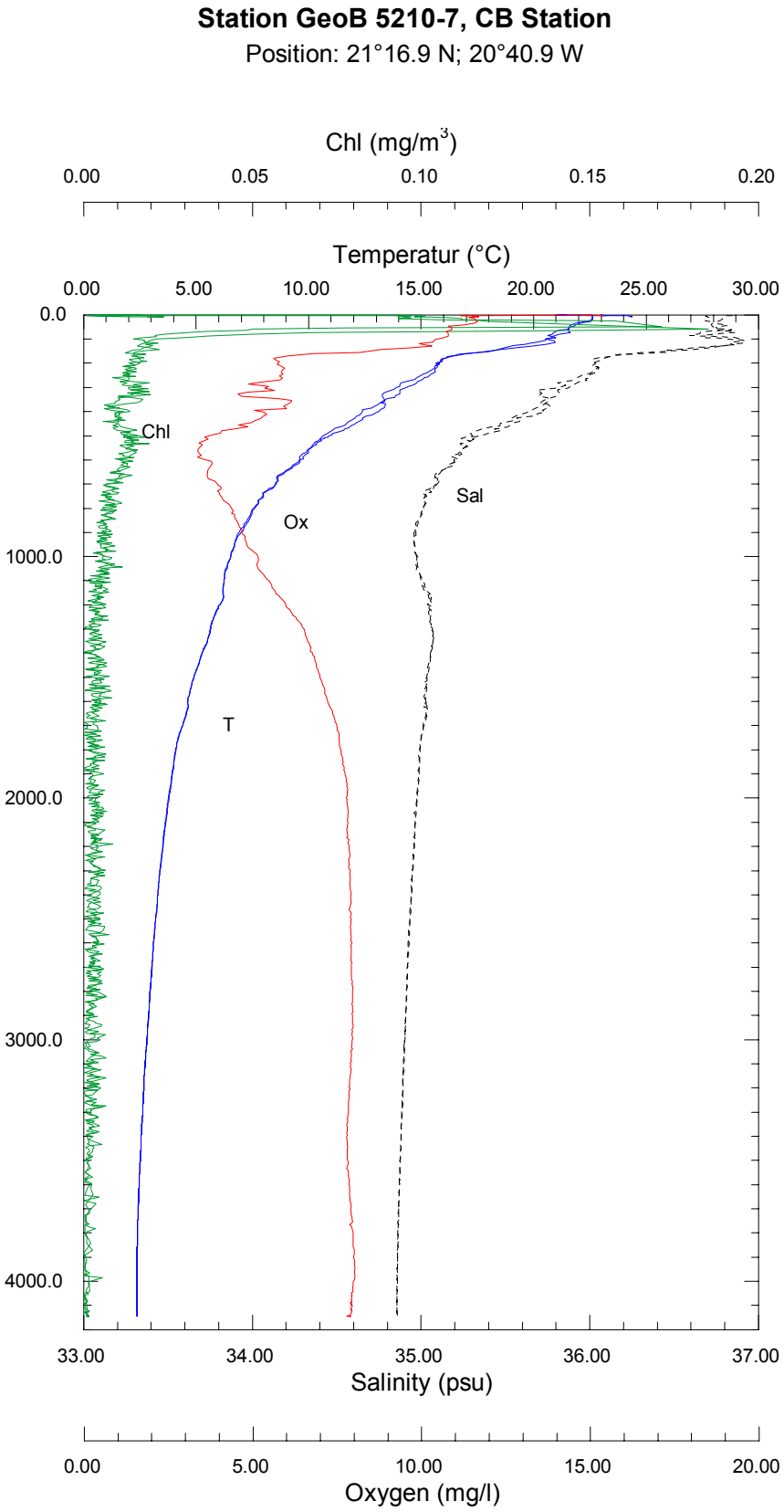

Figure 120a: CTD-depth (m)-profile from site Cape Blanc (see Figure 4).

b.

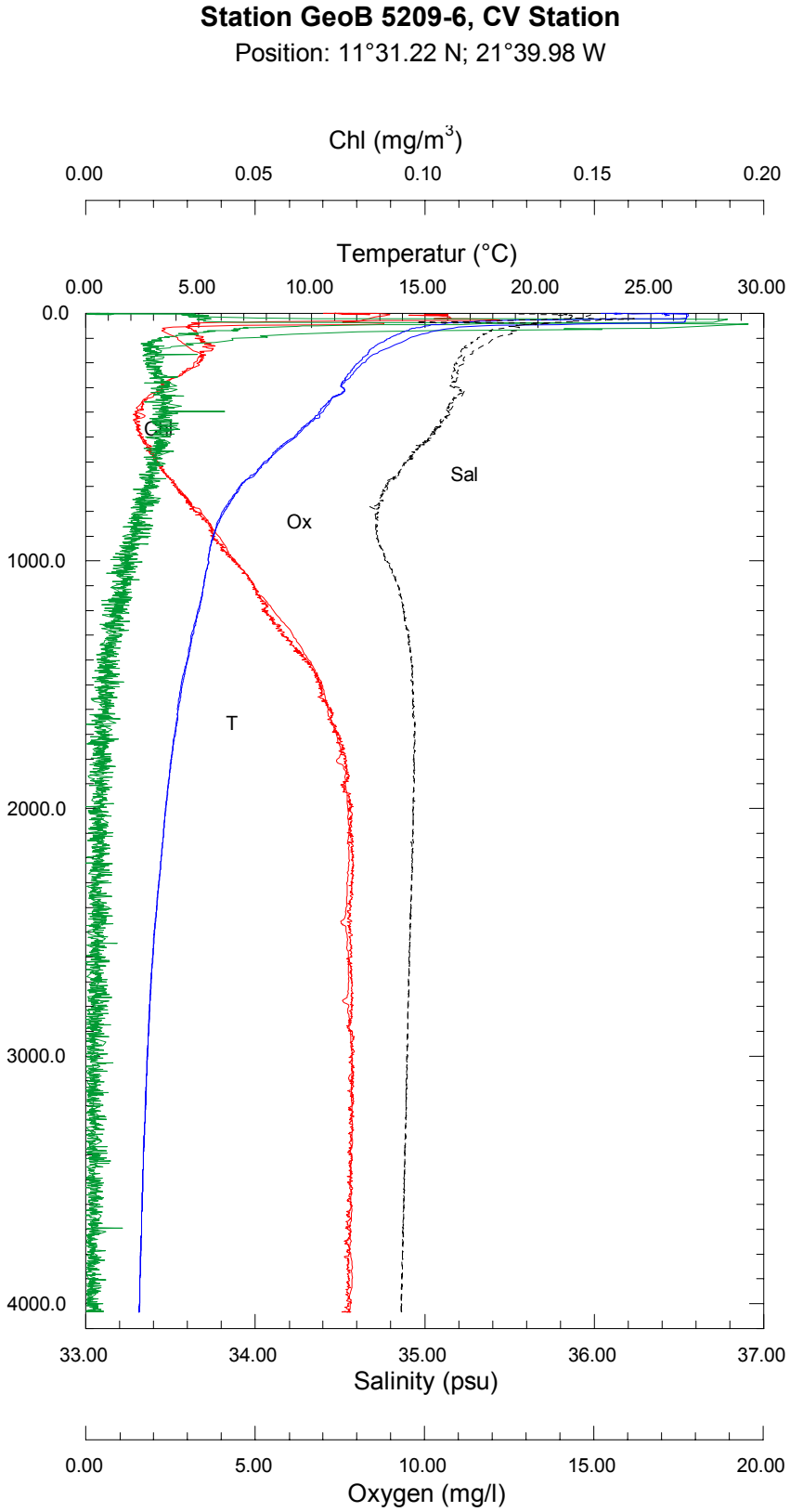

Figure 120b: CTD-depth (m)-profile from site Cape Verde (see Figure 4).

c.

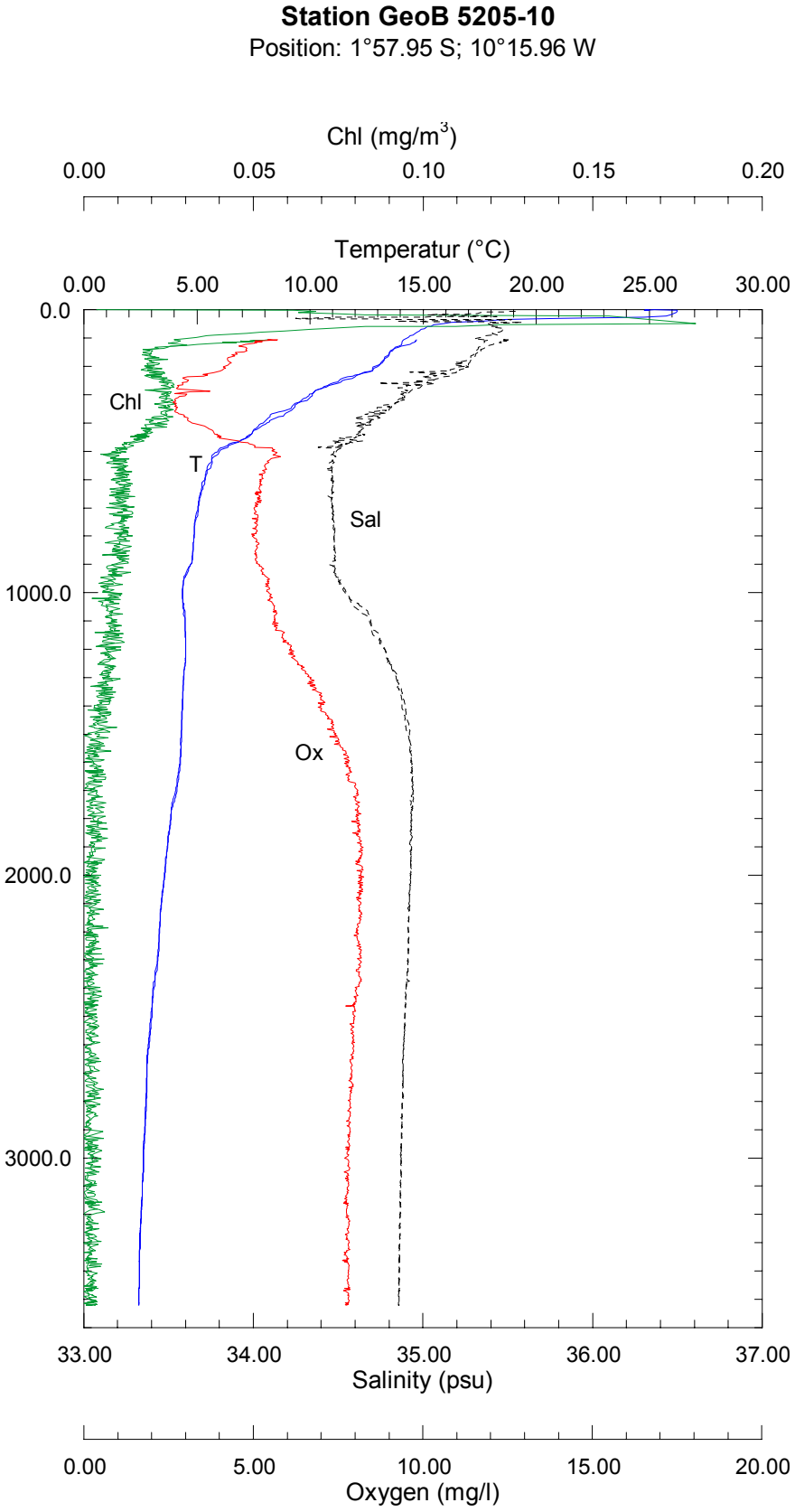

Figure 120c: CTD-depth (m)-profile from the eastern Equatorial Atlantic upwelling area (see Figure 4).

d.

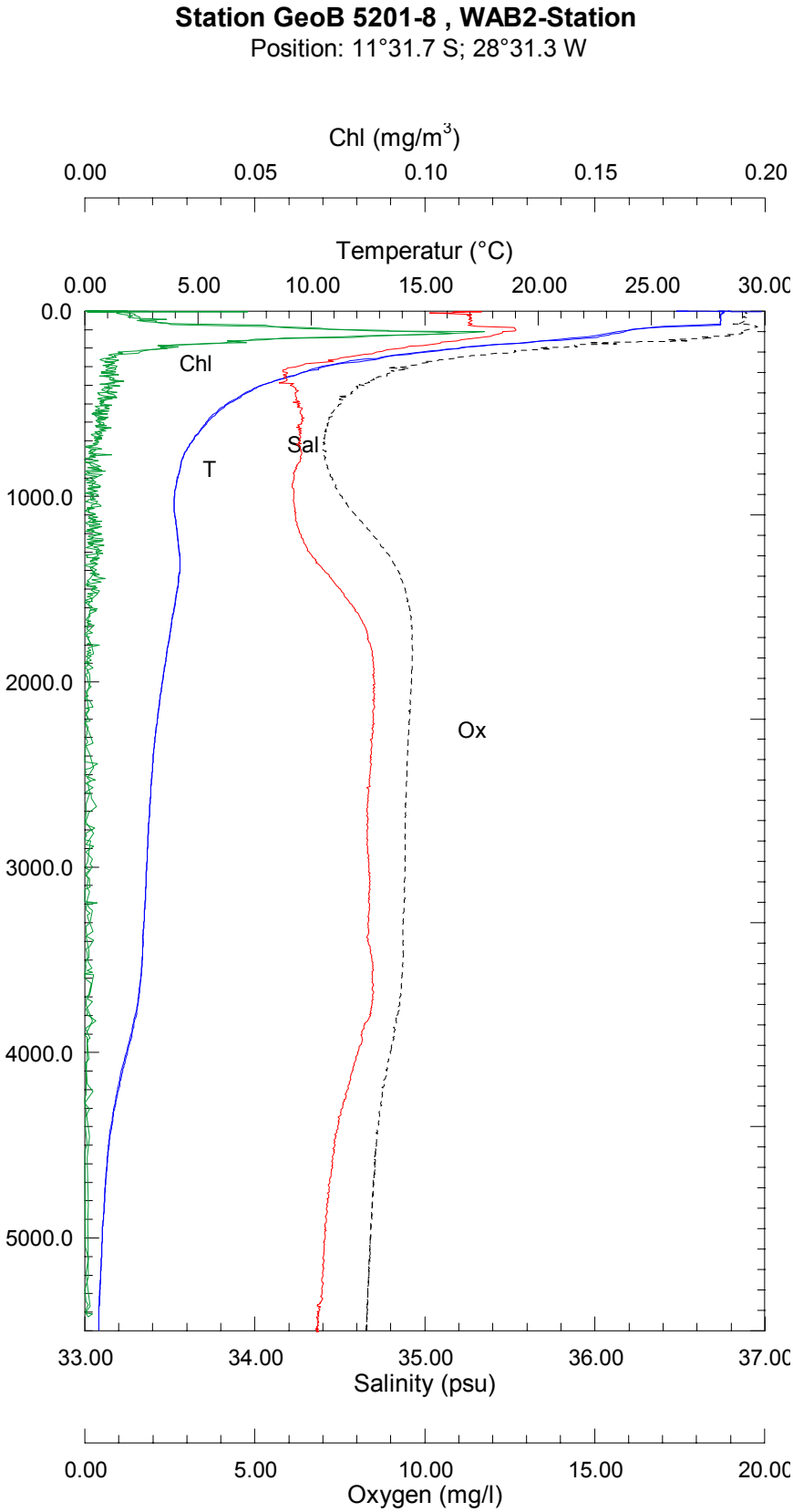

Figure 120d: CTD-depth (m)-profile from the central Brasil Basin (see Figure 4).

Chl-values appear to be lower below the thermocline (< 0.02 mg/l) when compared to the eastern sites. Lowest chlorophyll values were measured below 2000 m at the two southernmost stations GeoB 5202 and GeoB 5201. In the oligothrophic central Brasil Basin (GeoB 5201-8, Figure 120d), the Chl-maximum at 200 m depth reaches only 0.12 mg/l. The surface layer here is characterized by water temperatures above 28° and salinities of 36‰ and higher.

5.4.2 Marine Chemistry

(M. Gabriel, K. Pape, T. Wilkop, H. Dierssen)

A major key for understanding the biogeochemical cycling of chemical elements in the ocean are particle-water interaction processes. The main objectives during this cruise were to increase our knowledge about the control of trace element distribution in the water column which interact with biogenic and abiotic particles and to investigate how particle sedimentation in a high and low productivity region effects the vertical trace element distribution. The sampling strategy was to collect water samples and samples of suspended particulate material (SPM) from eleven stations (WAB2, WA12, WA4, WA15, EA4, EA3, EA2, EA1, CV, CB). Subsamples were taken from four sites with multi-sample sediment traps; three of them (WAB2, WA12 and WA15) were deployed on a SW-NE-transect during METEOR cruise 38/1 (see Figure 4). Another mooring were deployed off Cape Blanc (CB) on the same cruise. Sediment surface samples were recovered at three stations (WAB2, WA15 and Cap Blanc) with a multicorer to compare the trace element composition in the sediment with both kinds of the particles.

5.4.2.1 Water Sampling

From the stations off Cape Blanc (CB), Cape Verden (CV), four stations from the Eastern Atlantic EA4, EA3**,** EA2, EA1 and the four stations from the Western Atlantic WAB2, WA12, WA4 and WA15, twelve GoFlo-bottles from GENERAL OCEANICS were taken to analyze the vertical distribution of trace elements in the water column (10-1500 m). At the stations WA12, EA4, EA2 and CB, a second series of 12 GoFLo-bottles were taken to analyze the entire water column down to the depth of resuspension. To minimize contamination, GoFlo-bottles with pressure valves were employed, enabling the bottles to remain closed while passing through the surface layer. At a depth of 10-15 m, these bottles will open. For lowering through the water column, the GoFlo-water-sampler and the *in-situ* pumps were attached to a metal-free and non-greased KEVLAR® wire. All samples from the water column were collected rigorously applying clean sampling techniques to avoid contamination. All manipulations after subsampling were performed under clean benches in the lab onboard. A total of 152 water samples were collected for nutrients, oxygen and trace element analysis. The nutrients silicate, phosphate and nitrate were analyzed according to a standard photometric procedure. Immediately after collecting, oxygen content was determined by conventional Winkler titration. The resulting values show a similar depth profile than the oxygen sensor of the CTD-sonde. The absolute values, however, deviate somewhat from each other (see chapter 5.4.1).

After the water samples for trace elements were filtered through a polycarbonate filter (0,4 µm pore size, NUCLEPORE) in a plastic container, they were acidified with subboiled HNO_3 for storage. The trace elements (primarily Cd, Co, Cr, Cu, Mn, Ni and Pb) will be analyzed onshore with graphite furnance atomic absorption spectrometry (GF-AAS) after separation from the sea water matrix and preconcentration with an automated procedure using complexating resins (8-hydroxyquinoline/XE305). Total dissolved aluminium was directly determined employing a fluorometric method.

5.4.2.2 *In-situ* Filtration of Suspended Particles

At the same stations where sediment traps were recovered/redeployed and the other seven stations, suspended particulate material (SPM) was filtered using *in-situ* pumps at different depths (chapter 7.4.2). The filtered suspended particulate material is supposed to consist of slowly sinking biogenic and terrestrial detritus exhibiting a large surface area for sorptive processes. Due to the low concentration of SPM, larger volumes of sea water have to be filtered, if trace elements are to be analyzed in SPM. Between 20 l and 300 l sea water from depths down to 1000 m (at four stations down to the bottom) were filtered through acid cleaned polycarbonate filter (∅ 142 mm; 0,4 mm pore size, NUCLEPORE) using an *in-situ* pump from McLane. To reduce contamination, a metal-free and non-greased KEVLAR® wire was used and all handling of the filters was performed under a clean bench. From pump deployments, a total of 78 filters was obtained. The filters with the retained particles will be examined for trace elements later in the laboratory in Bremen. Aliquots of the material caught at the four mooring stations with intercepting sediment traps consists of larger, faster sinking particles which incorporated trace elements during their formation and by scavening of SPM; they will be analyzed in Bremen for trace and major components after digestion with nitric and hydrofluoric acid.

5.4.3 Plankton samples

Plankton sampling in the surface water along the ship's course serves several research objectives. Together with data from sediment traps and pumping stations, these investigations allow for a quantitative assessment of biomass and a first impression on the species distribution thoughout the South Atlantic.

5.4.3.1 Dinoflagellate investigations

(I. Flatter, A. Freesemann, B. Hönisch)

Dinoflagellates are unicellular organisms forming a major part of the marine plankton community. They live either autotrophic, heterotrophic or can use both nutrition strategies. As primary producers they are very important in the marine food web. During their life cycle they pass a vegetative cellulosic thecate stage. Being biflagellated during that stage they are able to swim actively. The only known exception, having a calcareous walled vegetative coccoid stage, is the species *Thoracosphaera heimii*. The second stage is marked by the formation of resting cysts.

The majority of the dinoflagellate species form organic-walled cysts. Only a few species form calcareous ones. Both cyst types as well as the coccoid stage of *Thoracosphaera heimii* are very resistant to degradation and can be found in recent and ancient oceanic sediments.

A number of studies showed that the resting cysts of dinoflagellates can be a very useful proxy for paleoceanographic reconstruction. However, the knowledge about dinoflagellates forming calcareous-walled resting cysts is still quite limited. For a better understanding of the palecological signals of this group it is necessary to investigate the recent geographic and vertical distribution of these organisms in comparison to the prevailing environmental parameters such as salinity, temperature, light, nutrient supply, stratification / mixing etc.. Furthermore, culturing experiments are a very useful tool for obtaining information about the ecological demands of the dinoflagellates. For these purposes water- and sediment samples were taken during the cruise.

Surface water samples

Surface water samples from a depth of approximately 5 m were collected between the stations three times a day (ca. 8:00 - 12:00; 13:00 - 17:00; 17:00 - 21:00 board time) using the ships membrane pump (chapter 7.4.3). A measured amount of water passed a 100 µm and a 5 µm filter and was concentrated down to 100 ml using a 5 µm polycarbonate filter and a vacuum pump system. These samples were qualitatively analysed with a light microscope and briefly described regarding their plankton content with emphasis on the calcareous-walled resting cysts of the dinoflagellates and the calcareous task of *Thoracosphaera heimii.* Some of the living cysts were isolated and placed in sterile polytrene Cell Wells™ containing 0,2 µm-filtered sea water and different types of culturing media (f/2 35%, K 35% and a 1:1 mixture of these with sea water) for future culturing experiments carried out at the University of Bremen. On board the Cell Wells™ were kept under light conditions of the local day / night cycle and a temperature of ca. 20°C. After the isolation step the water samples together with the filters were fixed using about 7 ml formaldehyde (37%) and stored in the dark at 4°C.

Water column studies

At ten stations water samples from nine various depths were acquired (chapter 7.4.4) using a rosette (Multi Water Sampler MWS, cat. nr. 436918A). Three to four of the 10 l NISKIN-bottles were closed at each depth, so the rosette had to be used twice at each station. The water was passed over a 100 µm mesh sieve (DIN 4188) and filtered using a vacuum pump in order to concentrate the samples to a volume of 100 ml per depth. These samples then were treated in the same way as the surface water samples taken with the membrane pump.

Light measurements

Photosynthetic organisms require different light regimes depending on their particular photosynthetic pigments. Thus the comparison of the depth distribution of autotrophic dinoflagellates and the corresponding underwater irradiance properties might elucidate patterns of preferred depths and migration. The MER-2040 Profiling Spectroradiometer (Biospherical Instruments) allows monitoring of apparent optical properties during vertical profiles from the ship. In addition to a PAR broad-band (400-700 nm) sensor, 14 down- and 14 upwelling monochromatic sensors (narrow bandwidths) measure the spectral irradiance. At nine stations light profiles were recorded (chapter 7.4.5). All profiles were driven at a winch speed of 0,1 m/

sec. The maximum depth (ropelength) equals the 1% PAR-limit and thus the lower boundary of the euphotic zone. Lateron, the data will be related to surface irradiance measurements. The real depth data, given by a pressure transducer, will also be calculated later.

Surface sediment samples

At three stations sediment samples were taken from one core (9,5 cm in diameter) of the multicorer (chapter 7.4.6). The surface sediments (fluffy material of the upper cm of the core) together with some of the bottom water were stored in petri dishes. The remaining core was cut into slices of 1 cm and also stored in petri dishes at 4°C. The aim of further investigations is to analyse the dinoflagellate cyst content, its changes in time and to compare it with environmental factors in order to gain information about climatic changes.

Preliminary results

Motile dinoflagellates as well as their cysts were found in almost all water samples. The samples derived from the lower part of the profiles contained mainly empty cysts. Motile thecate dinoflagellates occurred in every depth down to 200 m but were more abundant above 75 m water depht. All samples showed rather low numbers of calcareous resting cysts. Against the expectations, the same is true for the coccoid stage of *Thoracosphaera heimii*. In all water samples the association of calcareous cysts is predominated by the species *?Sphaerodinella albatrosiana*. The cyst species *Orthopithonella granifera* occurred sporadically, especially in the samples from stations GeoB 5207, 5208 and 5210 (East-Atlantic). Generally, highest amounts of cysts were observed in the material acquired at stations GeoB 5204, 5207 and 5208 (Mid-Atlantic Ridge and East-Atlantic) where salinity of the upper water masses is considerably lower than in the West-Atlantic. Other species of calcareous cysts did not occur or were detected just a few times. In the profiles no clear depth-related maximum of cyst concentration was noticed. In some profiles a slightly higher concentration occured at dephts of 50 m or 75 m, rarely at 120 m. Organic-walled dinoflagellates were present in most samples and every depth. However, they seem to be more abundant in the upper 20 m of the water column. Regarding the water samples aquired with the membrane pump, no significant differences in cyst composition and quantity could be seen between samples taken at different times of the day. In the membrane pump samples the concentration of calcareous cysts and of the plankton in general was higher compared to the samples taken with the rosette. Of course, this is partly caused by the greater amount of water represented by the membrane pump samples.

To summarize the light measurements, it can be stated that in general the light penetration was deepest in the western part and decreased towards the East-Atlantic. At stations GeoB 5205, 5209 and 5210 significantly shallower penetration depths were measured. For station GeoB 5205 this is explained by the early daytime of the measurement and thus the low angle of the sun. Data at station GeoB 5209 showed a normal exponential decrease with depth and below 40 m the light suddenly diminished. This, as well as the small penetration depth at station GeoB 5210, can be related to the presence of high plankton abundances in these depths: high numbers of different diatom species (50 m, station GeoB 5209) and numerous motile dinoflagellates (10 m and 20 m, station GeoB 5210).

5.4.3.2 Coccolithophore Communities

(R. Huber, J. Brüning)

In the present day oceans over 150 known species of coccolithophorids are known (HAQ AND BOERSMA, 1978). These autotrophic, marine algae (Prymnesiophyceae) are biflagellate or coccoid unicells, whose longest dimensions rarely exceed 30 µm and are most often smaller than 10 µm (HEIMDAL, 1993). They produce numerous external carbonate plates, named coccoliths which are a major component in almost all pelagic sediments. The occurrence and distribution of coccolithophores closely correspond to the hydrography of the water masses.

Today, relatively sparse information about their seasonal and spatial abundance and ecology in the surface water is available. Therefore, an investigation of the living coccolithophore communities in the South Atlantic was carried out in the uppermost water column. The water samples taken during this cruise will allow a better understanding of the relationship between living communities and the assemblages in the sediments. At 10 stations 2 l water samples were taken from NISKIN-bottles of the rosette at 200 m, 150 m, 100 m, 75 m, 50 m, and 20 m water depth (see chapter 7.4.7). In addition, 30 surface water samples were taken from the vessel's membrane pump system at about 5 m water depth (chapter 7.4.8). Samples were taken about every second longitude plus every latitude, except in the 200nm zone of Brazil, Cape Verde and Spain. Collection time usually was at dawn, high noon and twilight. Generally, two liters of the water samples were filtered through cellulose nitrate filters (50 mm diameter, 0,45 µm pore size) by a vacuum pump immediately. The total filtration area of the sartorius glass vacuum filter holder is 12.5 cm^2.

Without washing, rinsing or chemical conservation the filters were dried at 50°C for at least 24 h and then kept permanently dry with silica gel in transparent film to protect them from humidity. The filtered material will be used for studies on the distribution and composition of the coccolithophorid communities in the upper 200 m of the water column using Scanning Electron Microscope (SEM). Species composition and abundance will be determined by identification and counting on measured filter transects.

5.4.3.3 Pumped Samples for Diatom and Silicoflagellate Analysis

(G. Mollenhauer, H. Kuhlmann)

To qualitatively assess the diatom and silicoflagellate commutinies of the surface water in the Equatorial Atlantic and to compare them with the associations collected in the sediment traps, daily plankton samples were taken when sailing in international waters. Approximately 3000 litres of surface water from the shipboard installed seawater pump („Kreiselpumpe") were filtered through a 20 mm meshsize net during the period from 10 am and 4 pm local time (chapter 7.4.9). After stopping the water flow, the plankton was washed into 1 l KAUTEX plastic bottles, fixed with formaldehyde 37 % and stored at 4°C until further laboratory examination in Bremen.

5.4.3.4 Chlorophyll-a Measurements

(Mollenhauer, H. Kuhlmann)

For the determination of chlorophyll-a concentrations in the surface waters, seawater from the shipboard installed seawater pump („Membranpumpe“) was sampled at three times daily (8 am, 12 o'clock and 6 pm local time) when sailing in international waters (chapter 7.4.10). Two portions of 0.5 l seawater each were filtered onto a glass microfibre filter (Whatman, GF/F, 25 mm diameter). The samples were frozen at dark and will be analyzed by means of photometry at the laboratory in Bremen. The chlorophyll-a data should give information on seasonal and regional variability in biomass distribution. The results will be compared with satellite-derived chlorophyll concentration maps and may serve as calibration of these data.

5.4.3.5 Plankton and Water Sampling using a Multiple Closing Net

(H. Kuhlmann, G. Mollenhauer)

Plankton was sampled with a multiple closing net (Fa. HYDROBIOS) with 0.25 m^2 opening and 64 µm mesh size. It was used for vertical hawls at 10 sites (chapter 7.4.11). Each multinet station, except station GeoB 5209 where only the 1. and the 3. hawl were taken, comprised three hawls with:

1. depth intervals from 500-300, 300-200, 200-100, 100-50 and 50-0 m.
2. depth intervals from 400-200, 200-100, 100-40, 40-20 and 20-0 m.
3. depth intervals from 250-100, 100-75, 75-50, 50-25 and 25-0 m.

Hawl 1 will be used for studies on planktonic foraminifera, hawl 2 for radiolarian and diatom analyses, and hawl 3 for geochemical and isotopic analyses. The samples containing mostly zooplankton and some phytoplankton were carefully rinsed with seawater into KAUTEX bottles, fixed with mercury chloride for the reduction of bacterial degradation, and stored at 4°C. At all stations, 1.5 l NISKIN-bottles were used during the first and the third hawl to obtain water samples from the different water depths for analyses of carbon and oxygen stable isotopes and phytoplankton investigations.

5.4.4 Sampling of Eolian Dust

(V. Ratmeyer, R. Huber)

Eolian dust was sampled during intervals shown in chapter 7.4.12. However, depending on relative wind direction and -strength only several intervals were suitable for sampling. In order to avoid pollution from particles delivered by the chimney of the ship no sampling was done when the relative wind direction was in between 130° and 230°, and during station work. Sampling started on 29.05. and was continued until 12.06.1998. The dust samplers consist of a vacuum-cleaner motor and a frame to put the filter on. The size of the filters is 20.3*24.5 cm. One of the dust samplers has a “critical-flow ventouri” which forces a flux of 1.13 m^3 per minute. The flux of the other dust collector normally is calculated by measuring the pressure drop over the filter

but due to computer breakdown this could not be established. The flux is estimated to be about 2 m^3 per minute.

At each sampling interval the two dust collectors were used, each with its own particular type of filter. Glass-fibre filters were used for future studies with stress on the organic content of the eolian dust. After sampling, these filters were wrapped in alu foil and stored at -20°C. Organic-geochemistry measurements will be carried out at the biogeochemical department at the NIOZ. Cellulose filters were used in order to be able to study the terrigenous fraction part of the eolian dust. These filters were stored at room temperature. The siliciclastic fraction of the eolian dust will be obtained by dissolving the filter in H_2O_2. Clay mineralogy will be studied using XRD (NIOZ). Grain-size distributions will be measured using a laser particle sizer, major elements will be analysed using XRF and ICP (Utrecht University).

5.4.5 *In-situ* Particle Camera System (ParCa II)

(V. Ratmeyer)

For measuring the vertical particle concentration, size distribution and aggregate composition in the water column, a video in-situ camera system was build and used during M41-4. A new CCD-based videocamera was equipped with controlling electronics and highly collimating strobelights. The videosystem was tested on and calibrated inside a seawater-filled basin on deck prior to deployment for image sharpness and instrument electronics. Development and instrument testing could be successfully finished at the northernmost EA-Station. Two profiles were then taken at station GeoB 5209 and at station GeoB 5210.

The system was designed and improved in consideration of similar systems used by HONJO ET AL.(1984), ASPER (1987), LAMPITT (1985) and RATMEYER AND WEFER (1996). This method provides *in-situ* information on the origin and abundance of particles and aggregates (marine snow). In addition to the use of sediment traps, particle flux can be measured also in areas or depths with high lateral transport.

The aim of deployment during M41-4 was to observe the deep-sea particle population and abundance of large amorphous aggregates in the open ocean. Videographic abundance profiles were made on the mooring stations CV (4000 m) and CB (1500 m) (chapter 7.4.13). Due to a camera- malfunction, the first profile constists of images only down to 880 m waterdepth. The videos show variable particle and plankton concentrations, with highest concentrations in the upper 100 m. This correlates to previous measurements with particle camera and chlorophyll sensors in the Brasil Basin (RATMEYER AND WEFER, 1996). Different species of plankton and makroplankton can be identified on the images, including foraminifera, pteropods, copepods and medusa. Particle and aggregate sizes vary from 200 µm to > 10 cm. Quantitative analysis of concentration, shape and size of particles will be performed using a PC-based image analysis system. This was not possible during the cruise and will be done in Bremen.

However, first results show a higher abundance of particles in the southernmost profile (GeoB 5209), were very large, amorphous aggregates (so-called stringers) could be observed. These

"stringers" are most probably responsible for a large part of the verticle particle transport from surface waters to the deep sea, as they consist of mucus fathoms scavenging smaller particles from the water column on their way down. The second profile at GeoB 5210 shows a higher abundance of zooplankton in the upper 150 m, but much less large particles with sizes > 1000 µm compared to the GeoB 5209 station. A similar trend is visible in the chlorophyll profiles from both stations: Within the the upper 1000 m of the water column, values at GeoB 5210 are almost twice the values at GeoB 5209. A possible explanation for these differences within the same large region of coastal upwelling gives the MUC taken at GeoB 5210: A green-brownish fluffy layer of organic material was observed on top of the sediment surface. The color and fluffy character of this organic material shows that it cannot be very old. A conclusion might be, that the relatively low particle concentrations in the water column are a result of a previous "fallout" event, were larger particles and aggregates "washed out" the water column and were finally deposited on the sediment.

The ParCa II system consists of the following components:
The Video-System constists of a modified SONY VX 1000 digital 3-chip CCD camera controlled by two PIC-microprocessors. The illumination is provided through a high-precision strobe head manufactured by DeepSea Power & Light. Strobe rates can be switched between 1 Hz and 50 Hz, the trigger signal is synchronized with the framerate of the videocamera. Programming and testing of the camera can be done using serial RS232 communication. Different test-programs were tested and run inside a deck-mounted seawater basin, in order to find the best relation between probe-volume, zoom-factor, illumination, repetition rate and size-resolution. Finally a winch speed of 0.3 m/s was found to meet both sufficient speed and sharp images without smear effects. The system is fixed inside a collapsible frame of the dimension 100 x 500 x 200 cm, which is made of 48 mm hot galvanized steel pipe. The complete system weight is approximately 150 kg in air. The ParCa II system will be further improved during following cruises, concerning different zoom-stages, different illuminations and an automated *in-situ* image analysis. Online video and RS232 communication during deployment will be another aim of further development.

5.4.6 Particle Collection with Sediment Traps

(G. Ruhland, V. Ratmeyer, G. Fischer)

The data of deployment and recovery of the moorings are listed in chapter 7.4.14 together with the sampling data of the traps. Three moorings were recovered in the western equatorial South Atlantic; another system was recovered off Cape Blanc. All arrays were redeployed on their original positions (Figure 4). The first one was located in the oligotrophic central Brazil Basin. The other moorings were deployed in the more productive northern Brazil Basin and in the western equatorial upwelling area. The arrays were equipped each with two multisample traps and one current meter. All moorings are planned to be recovered by RV METEOR (M46/1) in November, 1999.

On May, 21st the mooring WAB1 was recovered on the southernmost position in the central Brazil Basin. The array was equipped with two multisample particle traps in 727 m and 4515 m water depth. A current meter was placed 20 m below the upper trap. Additionally an inclinometer

was fitted to the upper trap. The traps started sampling February 27th, 1997 with an sampling interval of 22.5 days, except for the first and last cups (each 21.5 days). The instruments worked well except of the inclinometer which did not record data due to low battery power. At the same day, the mooring was redeployed as WAB2 with the same configuration except of the inclinometer. The traps were programmed for a 27.5 day interval starting at May, 22th 1998, the last cup was scheduled for a 30.5 day interval.

On May 23th, the mooring WA13 was recovered successfully at a site located in the lower productive subtropical gyre of the northern Brazil Basin. This mooring array was equipped with two multisample traps in 871 and 4736 m and one current meter in 895 m water depth. Both traps provided a complete sequence of samples but the lower one stopped at the first cup due to an unknown error. Therefore, the first sample was lost. The traps were programmed for 22.5 day sampling intervals starting on February 25th, 1997.

The moored current meter recorded no data due to an low power failure of the lithium battery. At the same day, the mooring array was redeployed again as WA14 at the same position. The traps were scheduled for a 27.5 day sampling interval starting May 24th, 1998. To synchronize the sample intervals for all moorings, the first cup changed after 25.5 days. The last sample interval will be 28.5 days.

The third mooring WA12 was recovered on May 27th. This mooring was located in the western equatorial upwelling area. The two moored traps in 688 and 3173 m depth worked perfectly and provided two sample sets of 20 samples each. Each sample covers a time interval of 22.5 days for each sample except for the first cup (26.5 days) and the last cup (24.5 days). The current meter registered data for the complete deployment time in 712 m water depth. At the same day, a similar mooring named WA15 was redeployed at the same position. The traps started sampling on May 28th.

The mooring CB8 was recovered successfully at a site located in the filamental zone of the coastal upwelling area off Cape Blanc on June, 9th. This array was deployed as all other moorings during the METEOR cruise M38/1. It was equipped with two multisample particle traps in 745 and 3579 m water depth. One current meter was placed 24 m below the upper trap. The traps both provided a full sample set with a sample interval of 24.5 days. Also the current meter recorded data for the entire deployment time. On June 10th, a comparable mooring was redeployed at the same position named CB9. This mooring contained two particle traps in 746 m and 3580 m water depth and a current meter in 770 m depth. The sample interval for these traps was 27.5 days except for the first cup (7.5 days) and the last (11.5 days).

Preliminary Results

Particle flux at the oligotrophic Brazil Basin (site WAB1) was the lowest of all sites in the westen tropical Atlantic (Figure 121). Seasonality was also the lowest with respect to the upper trap levels. The deeper WAB1 trap showed lower fluxes than the upper one. As expected, fluxes and seasonality increased towards the north in the western equatorial upwelling regime. Maxima occurred in winter but mainly in spring and summer at sites WA13 (at 7°S) and WA12 (equator) (Figures 122 and 123). In most cases, the deeper traps revealed lower fluxes compared

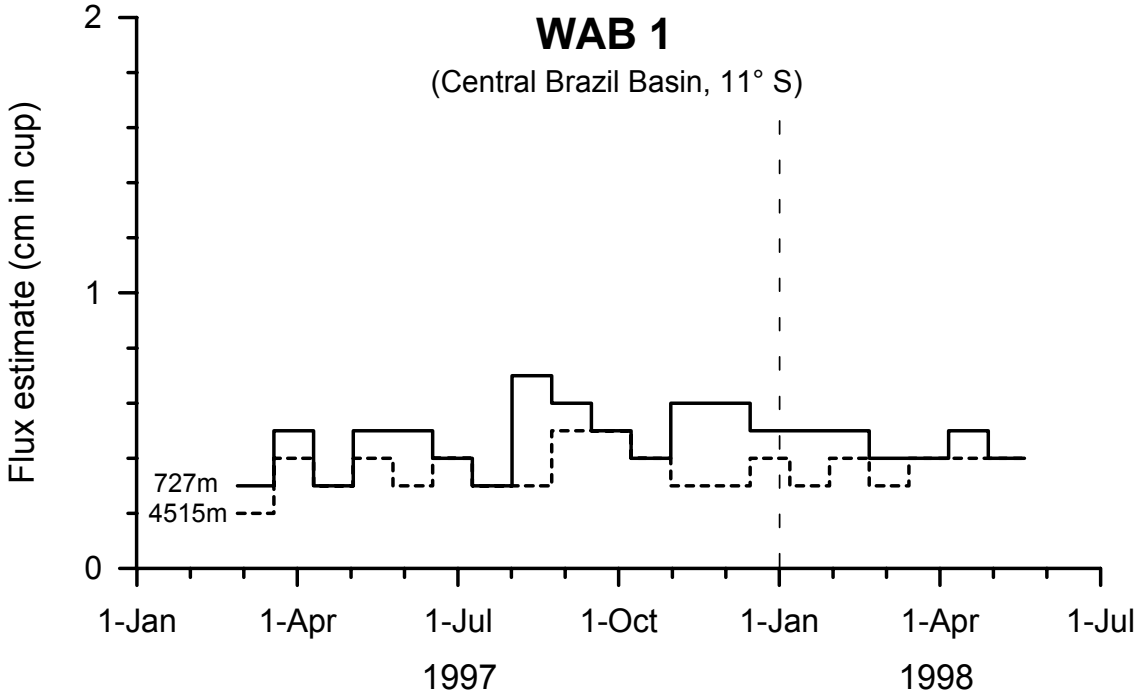

Figure 121: Flux estimate at site WAB1. For location see chapter 7.4.14 and Figure 4.

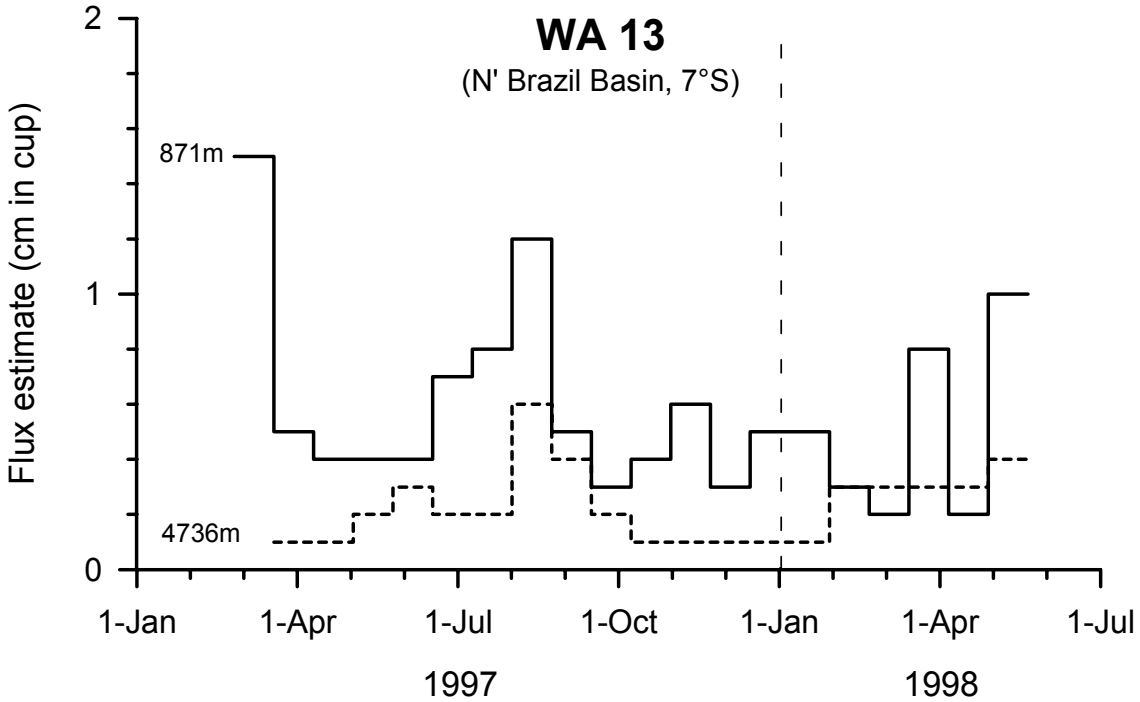

Figure 122: Flux estimate at site WA13. For location see chapter 7.4.14 and Figure 4.

to the upper ones. Thus, no strong influence of lateral transported material or strong resuspension at the seafloor seemed to occur. At site Cape Blanc (CB8), only the upper trap worked perfectly, the lower one sampled only 3 periods with a lot of material in cup 3. Unfortunately, this trap was recovered upside down and the material which obviously was anoxic was lost. The upper trap

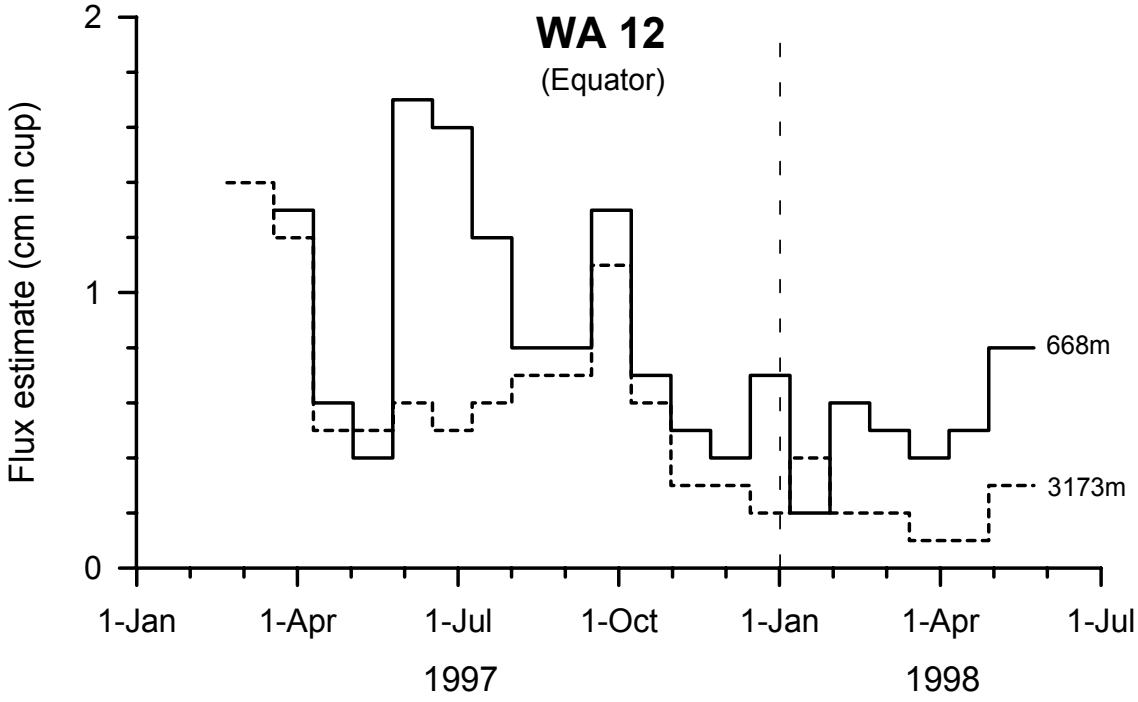

Figure 123: Flux estimate at site WA12. For location see chapter 7.4.14 and Figure 4.

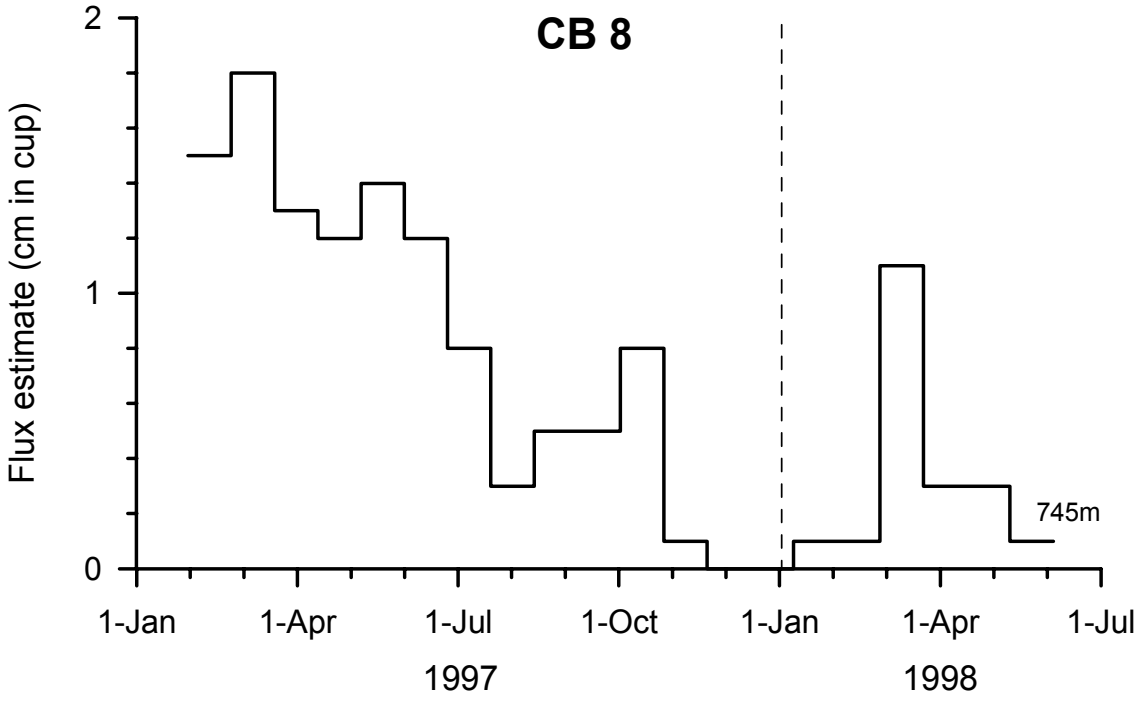

Figure 124: Flux estimate at site CB8 off Cape Blanc. For location see chapter 7.4.14 and Figure 4.

collected much material and showed a strong seasonality (Figure 124). High fluxes were estimated for winter and spring and fall 1997 showing a strong decline towards the end of the year and in winter 1998. The spring peak in 1998 was much lower compared to 1997.

5.4.7 Marine Geology

(G. Mollenhauer)

To complement the data collected by the moored sediment traps, multicorer sediment and bottom water samples were taken at the mooring stations. Undisturbed seafloor surfaces and cores of the upper few centimeters of the sediment as well as bottom water samples provide important additional information to understand the sedimentary environment at the mooring sites. The data obtained through coring combined with the analysis of the trapped sediment helps budgeting the flux through the water column. During this cruise, only a multicorer was used. No gravity cores were retrieved.

5.4.7.1 Multicorer Samples

For the sampling of complete and undisturbed sediment surfaces and the overlying bottom water, a multicorer (MUC) equipped with six large (10 cm diameter) and four small (6 cm diameter) tubes was used. Core recovery was good at all stations. Penetration depths range from 15 cm at the Mid Atlantic Ridge to 42 cm in the Brazil Basin (chapter 7.4.15).

Sampling

Sediment from the MUC tubes was sampled as follows:

- one large tube cut into slices of 1 cm thickness was frozen for organic carbon (TOC) measurements, bottom water samples were taken for stable isotope analysis (2 x 50 ml for $\delta^{13}C$, poisoned with mecury chloride, 1 x 50 ml for $\delta^{18}O$; water sample bottles were sealed with hot wax and stored at 4°C).
- two large tubes were cut into slices of 1 cm, filled into KAUTEX plastic bottles and fixed with a solution of rose begal in ethanol (1g/l) and stored at 4°C for the study of foraminifera.
- one large tube was cut into 1 cm slices and stored at 4°C for investigation of dinoflagellate communities (top 1 cm bottom water included).
- one large tube was cut into slices of 1 cm thickness and frozen for the study of coccolithophorid communities.
- one large tube was used for trace metal analysis. The bottom water was sampled, the top 2 cm of the sediment were cut into 0.5 cm slices, the sediment between 2 and 10 cm core depth was cut into slices of 1 cm thickness, the rest of the core was sampled in 2 cm slices. The outer part of the sediment was scraped off to avoid contamination by contact with the tubes. Sediment samples were frozen, water samples were analyzed for nutrients and oxygen in the shipboard labs.
- The surface of one small tube was taken for radiolaria and diatom investigations, the rest of the sediment was frozen as an archive core.
- three small tubes were frozen as archive cores.

Lithology of the Surface Sediments

GeoB 5201-8; *11°31.7'S, 28°31.2'W*
At this location in the Central Brazil Basin where the mooring station WAB 1/2 is located, ten multicorer tubes of surface sediment and the overlying bottom water were retrieved out of a water depth of 5461 m. The maximum penetration depth was 42 cm. The sediment is clayey. Its colour is grey-brownish (soil colour chart # 2.5Y5/4) at the top 22 cm and changes to grey-brown-yellow further down the core. A general trend to lighter colour can be observed downcore. Contrary to the general decrease in water content downcore, a layer of higher water content occurs at 27 cm core length. Bioturbation is intense and obvious throughout the whole core.

GeoB 5204-11*; 00°00.6'N, 23°29.1'W*
At the site of the mooring station WA 12/15 on the eastern flank of the Mid Atlantic Ridge, ten multicorer tubes of sediment and overlying bottom water were recovered. The water depth at this site is 3701 m. The maximum length of the cores is 16 cm. The sediment retrieved is a clayey foraminifera ooze. The carbonate content of the sediment is high. Especially at the sediment surface, the grain size of the foraminifera tests is in the coarse sand fraction. The top of the sediment core is grey (soil colour chart # 2.5Y5/2 or 2.5Y6/2), changing to grey yellowish (soil colour chart # 5Y6/2) at a depth 9 cm down the core. This colour change was interpreted at the transgression from the last glacial to the present interglacial. At a core depth of 7 to 8 cm, black spots are observed. Bioturbation is visible throughout the whole core length.

GeoB 5210-7*; 21°16.8'N, 20°41.0'W*
At the position of the mooring station CB 8/9, 6 large and 4 small tubes of surface sediment were recovered out of 4150 m water depth. The maximum core length is 34 cm. The sediment consists of clayey foraminifera ooze, the grain size of the foraminifera tests is medium to coarse sand. The colour of the sediment changes from yellowish light grey-brown (soil colour chart # 2.5Y7/4 at the top, # 2.5Y7/3 at 7 cm core length) to light grey-brown with black spots downcore from 22 cm core length (soil colour chart # 2.5Y7/2). No bioturbation or any other sedimentary structures could be observed. The sediment surface was wavy. Partly decayed organic material (fluff) was deposited on the surface of the cores. On one of the coretops, there was a fragment of a calcareous algae.

5.4.8 Profiling Hydroacoustic Systems

(G. Mollenhauer)

During METEOR Cruise M 41/4 the shipboard hydroacoustic systems HYDROSWEEP and PARASOUND were operated only at the mooring and coring sites to select appropriate coring locations for the multicorer device. The two systems are valuable tools to examine seafloor topography and sedimentary characteristics. Information on these parameters is essential for successful coring and helps interpreting the core material.

5.4.8.1 HYDROSWEEP

This multibeam sounder provides bathymetric data. It employs a swath of echobeams with a width of twice the water depth. Thus, a topographic map of the ocean floor along the ship's course is obtained, the breadth of which varies with water depth. Knowing the local topography of a coring site is essential to evaluate the impact of morphology, slope angles, sediment instabilities, and erosion on the sedimentary environment. The system worked reliably without any technical problems.

5.4.8.2 PARASOUND

The sediment echosounder system PARASOUND gives information on the internal structure of the sedimentary cover of the oceanfloor by means of high frequency (4 kHz) seismograms. The penetration of the signal is determined by the density and acoustic impedance of the sediment layers. Therefore, the penetration depth and the reflector characteristics of the ocean floor are important information on the physical properties of the sediment and the suitability of a certain site for coring. The echosounding data at the coring locations were digitized and stored by using the software package PARADIGMA. The online plots of the seismograms were the predominant criterion for the selection of a coring site.

6 SHIP'S METEOROLOGICAL STATION

6.1 Weather and Meteorological Conditions during M41/1

(C. Joppich)

The weather at the beginning of the cruise was dominated by a high over France and Spain. Strong easterly winds occurred in the western Mediterranean, growing up to Bft 8 in the strait of Gibraltar for a short time. Soon after passing Gibraltar winds calmed down to Bft 4. Near the coast of Morocco fog patches arose for a few hours. On the way to the Canary Islands northeasterly trade winds were weak due to a strong high over Algeria. From Canary Islands to Cape Verde the trade winds blew mostly parallel to the coast line, from northerly to northeasterly directions. During daytime the observed wind-speed rarely exceeded Bft 4, because the direction of the sea-breeze was opposite to the geostrophic wind. At night the wind-speed grew up to Bft 5 due to an amplifying effect of a moderate land-breeze. In the subtropical region the sky was free of clouds for several days, but there was a lot of dust in the air, reducing surface visibility sometimes below 5 km.

After passing Cape Verde, the cold Canary Current lost his influence and the sea surface temperature soon reached tropical values of 28 to 30 °C. The wind blew moderate (Bft 4) from northwesterly directions, parallel to the coastline of Sierra Leone. In the night from 20th to 21st of February METEOR crossed the intertropical convergence zone (ITCZ) at a latitude of about 5 degrees north.

The following days winds mostly blew from southerly to southwesterly directions with Bft 3 or Bft 4. Several times rain-showers of different intensity occurred. In vicinity of showers the wind veered northwest and freshened up to Bft 5.

A special meteorological phenomenon appeared in the forenoon of 23rd of February. Several severe rain-showers could be observed in the vicinity of METEOR and altogether three whirlwinds with associated water spouts developed in a distance of about 6 to 10 miles. Their appearance was like a needle prick down from the Cumulonimbus to the sea surface.
In the Gulf of Guinea and the Bight of Bonny it was cloudy but only few showers occurred. The air-temperature was similar to the water-temperature of 29 to 30 °C. Near the islands Principe and Sao Tome widespread mist or haze was present. Prevailing southwesterly winds did not exceed Bft 4 (only weak monsoon effects).

South of the equator similar weather conditions occurred. Winds mostly blew from south to southwest, veering west in showers and increasing to Bft 5 for a short time in their vicinity. In the same time, a well developed subtropical high over the southern Atlantic Ocean induced a strong southeasterly trade wind west of Namibia, which was modified to a moderate southerly to westerly breeze at the western coast of Angola. Therefore the weather at the southernmost part of the cruise was affected by these subtropical conditions. Showers occurred only over land near the coast line due to diurnal heating.

On the way back to Libreville some showers passed through north of 6.00 N and squalls from variable directions grew up to Bft 7 for a short time.

During the entire cruise the swell rarely exceeded 1.5 meters, only at the southernmost part, south of about 10.00 S, the swell reached values of 2.0 meters for a time, due to strong cyclic activity in the west-wind-belt over the southern Atlantic Ocean and strong southeasterly tradewinds south of 20.00 S.

The water-temperatures north of 15.00 N corresponded to the mean, but in the gulf of Guinea and south of it the observed water-temperatures were 1.0 to 1.5 C above the monthly mean values of many years.

6.2 Weather and Meteorological Conditions during M41/2

No meteorologists were on board during the second leg of cruise M41.

6.3 Weather and Meteorological Conditions during M41/3

(C. Knaack, D. Bassek)

The 3rd leg of RV METEOR cruise no. 41 began on April 18, 1998 at 08:15 local time in Vitória (Espirito Santo). The ship set out on a southerly course. A northerly wind of force 5, occasionally 6 was blowing, caused by an intense subtropical high lying over the eastern South Atlantic. During the first night, the cold front of a low off the south Brasilian coast crossed our route with thunderstorms and gusts.

On April 20 at noon, the first waypoint near 2°S / 41°W (Vema Channel) was reached. An upper trough brought some intense rain showers with gusts during the morning, later the weather was rather calm. A southwestern swell of about 3 m height did not affect the scientific work considerably. The next day RV METEOR reached the southernmost point of the cruise at 31.3°S / 39.3°W. High pressure influence favoured our research work, which included the deployment of a near bottom mooring. Course was then set northeastwards to the operational area in the northern part of the Vema Channel. The weather pattern during the next days was as follows: an anticyclone between Tristan da Cunha and South Africa connected by a high pressure ridge with another anticyclone over the western part of the ocean causing an easterly flow of approximately force 5. In front of a south Brasilian low which moved eastwards, the wind backed to the north on April 24 and to the northwest on April 25. A cold front caused increasing winds of force 6 to 7 and passed us with heavy rain showers accompanied by gusts. On the rear side of this „lull front“ the wind abated.

On April 28 a zonal section across the Mid-Atlantic Ridge began at 24°S / 20°W. The dominant high moved from a southwestern position to the east, causing mostly easterly winds between forces 1 and 5. Now and then, the typical calmness of the horse latitudes was observed. The southerly swell of 1.5 to 2.5 m height temporarily made the navigation during stations difficult,

as its direction differed from that of the wind. The high pressure influence lasted during the meridional section at 9°E and also during the final zonal section at 19°S from 9°W to 17°W.

With the help of our radio soundings during this time, the characteristic trade wind inversion was observed. From the surface up to 1200 - 1500 m height the temperature dropped from about 23°C to 11 - 13°C, reaching a maximum relative humidity. In the next layer of only a few hundred meters, the temperature increased up to 17 - 20°C. Above this level, temperature decreased with the tropospheric lapse rate of 0,65 K/100 m. Below the inversion, mostly flat cu clouds were observed, although almost overcast sc layers also appeared. From time to time humidity and instability caused convection with towering cu clouds and some rain showers. On April 29 a water spout occurred.

On May 10, 1998 the scientific work on board was completed. Over the last days of the cruise, rear winds of force 4 - 5 accompanied RV METEOR during the northwesterly route to Salvador (Bahia), where we arrived safely in the morning of May 15, 1998.

6.4 Weather and Meteorological Conditions during M41/4

(Christian Knaack)

Leg 4 of the RV METEOR cruise nr. 41 began on the 18th of May 1998 at 10:30 local time in Salvador (Bahia). The ship set out on an easterly course. At the northwestern edge of the subtropical high the trade winds of force 5 were blowing from east to southeast. The waves were composed by a sea of 2 m and a swell from southeast of 2,5 to 3 m height. Some showers occurred. On the 21st of May, the first waypoint at 11.5°S, 28.5°W was reached. The subtropical high had weakened. So the wind decreased to force 4, and the height of the waves was reduced to 1,5 m. The equator was crossed on the 26th of May. From the waypoint at 0.5°N, 24°W the ship sailed a distance of about 800 nm in an east to southeasterly direction. On the 30th of May METEOR reached the eastern most point of the cruise at 2°S, 10,5°W (Guinea Basin). At that time steady trade winds from of force 5, later 4, dominated.

On the 1st of June, the ship crossed the equator once more at 10.5°W. Soon the wind of force 5 veered from southeast (trade winds) to south/southwest. This is due to the gradually increasing Coriolis effect causing deflection to the right in the northern hemisphere. During the following days, the Intertropical Convergence Zone (ITCZ) was traversed. In the night from 3rd/4th June intense showers brought almost 40 mm of precipitation. Apart from some shower gusts, the wind abated: METEOR had reached the doldrums. A short meeting with RV POLARSTERN in the morning was favoured by weather with no showers and some sunny periods. In the afternoon new showers ocurred. Our radiosoundings showed a very humid and unstable layered troposphere with convection up to 13 km.

On the 6th of June, METEOR left the ITCZ having passed the thermal equator (air temperature 28°C, water temperature 29°C) the day before at 10°N. From now on the subtropical high southwest of the Azores was dominant. Its northeasterly trade winds were blowing mostly with

force 4 to 5. With the help of our radio soundings during this time, the characteristic trade wind inversion was observed.

The sounding of the 9th of June e. g. showed temperature inversion between 918 and 1250 m height with an increase of 7,2 K. Below the inversion, mostly flat cu clouds were observed, although somtimes almost overcast sc layers also appeared. Above the inversion layer the atmosphere was dry, and temperature decreased with the tropospheric lapse rate of 0,65 K/ 100 m. At 21°N, 21°W (off Cape Blanc) the scientific work on board was completed on the 10th of June.

During the last days of the cruise, the subtropical high moved to its characteristic location at the Azores. It became stronger with an air pressure of more than 1030 hPa causing an increase of the northeast trade winds, which were blowing with force 5, occasionally 6. As a result, the sea amounted to about 2,5 m height. In the morning of the 13th of June, METEOR arrived safely in Las Palmas (Gran Canaria, Spain).