5 Preliminary Results

5.1. Leg M45/1

5.1.1 Sediment Sampling with Gravity- and Multi Corer

(B. Meyer)

Gravity Corer

A gravity corer with different pipe lengths and a weight of 1.5 tons on top was used at 6 locations to be able to recover deeper sediment sequences. The core recovery ranges from 3.16 m to 5.33 m. Only the uppermost shelf location had the lowest core recovery of 23 cm (Tab. 3). The sediment cores has been cut into segments of 1 m each, described and stored at 4°C in the refrigerator storage rooms of METEOR.

Multi-Corer

The main tool for the recovery of undisturbed sediment surfaces and the overlying bottom water was the multi-corer equipped with 8 tubes of 10 cm and 4 smaller tubes of 5 cm in diameter. The multi-corer was used at the same locations of gravity cores (Tab. 3). The core recovery was good, typically 10 to 12 tubes were filled, and cores of very good were recovered.

At each multi-corer station, the overlying bottom water of one of the large tubes was sampled for stable isotope measurements at Bremen. Mostly 4 of the large tubes and 1 of the smaller tubes were usually sampled in 1 cm slices for analysis of C_{org}, benthic and planktonic foraminifera, coccoliths. The C_{org} samples were frozen immediately after collection at -27°C. Benthic foraminifera samples were stained with a solution of 1g of rose bengal in 1 l ethanol. A second set of non-stained samples was also collected for planktonic foraminiferal and coccolithophorides analysis. All the foraminifera and coccolithophoride samples were kept at 4° C. Mostly one large and/or one small core were frozen as archive material.

Table 3: Sampling locations in the Golf of Cadiz

St. No.	Device	Lat.	Lon.	water depth	recovery
5901-1	MUC	36 22,80 N	007 04,29 W	575	0.27 m
5901-2	SL 6	36 22,80 N	007 04,28 W	574	3.26 m
5902-1	SL 6	36 36,67 N	007 00,88 W	494	0
5902-2	SL 6	36 36,68 N	007 00,87 W	494	0.23 m
5902-3	MUC	36 36,67 N	007 00,87 W	494	0.22 m
5903-2	MUC	36 01,41 N	007 40,01 W	1094	0.40 m
5903-3	SL 12	36 01,43 N	007 40,00 W	1095	5.33 m
5904-1	SL 12	35 50,44 N	008 07,78 W	1996	5.18 m
5904-2	MUC	35 50,44 N	008 07,77 W	1997	0.20 m
5905-1	MUC	35 43,00 N	008 26,65 W	2436	0.16 m
5905-2	SL 12	35 42,99 N	008 26,66 W	2437	3.16 m
5906-1	SL 12	35 32,78 N	008 53,10 W	3029	3.49 m
5906-2	MUC	35 32,77 N	008 53,10 W	3026	0.17 m

5.1.2 Particle Flux Measurements with Moored Particle Traps

(V. Ratmeyer, G. Ruhland, U. Rosiak)

Particle flux measurements at the ESTOC (European Station for Time-series in the Ocean, Canary Islands) carried out since fall of 1991 show seasonal and short-term variability due to varying productivity and hydrographic conditions. This long-term particle flux record also indicates that a large portion of deep particle flux originates laterally. In CANIGO, additional sediment traps were placed north of La Palma (mooring LP), between the eastern Canary islands (mooring CI) and the Moroccan shelf (moorings EBC). Including the ESTOC position, these three main trap locations cover the productivity gradient from the shelf region to the oligotrophic gyre.

On 26 May the ESTOC sediment trap mooring CI10 was recovered. It carried three traps, two RCM 8 Aanderaa current meter and two particle pumps (Marine Chemistry department, Univ. of Bremen). The upper and mid-level sediment trap have worked well. The lower one have had failures. After servicing of the mooring equipment the CI mooring was re-deployed as CI11 (Fig. 10) at the same location. The CI11 mooring carries three sediment traps, two Aanderaa current meter and two particle pumps.

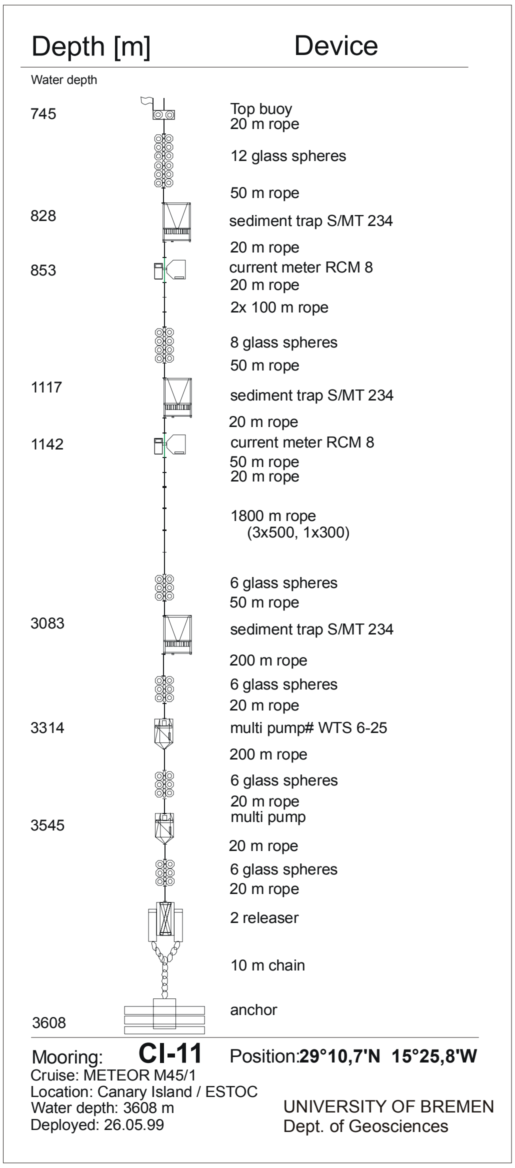

Fig. 10: Sediment trap mooring CI 11 deployed at ESTOC

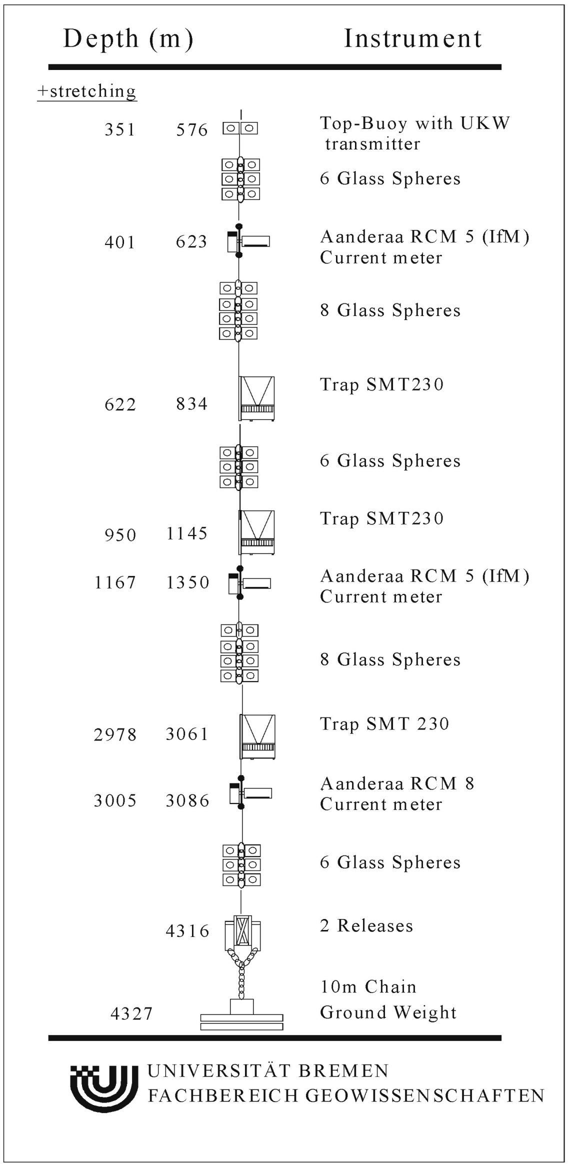

Fig. 11: Sediment trap mooring LP 3 recovered north of La Palma.

The La Palma sediment trap mooring LP 3 (Fig. 11) was recovered on 31 May 1999. It carried three sediment traps and 3 current meters. The uppermost sediment trap have worked well. The mid-level and the lower one have had failures. The mooring activities on this location were terminated and the mooring LP was not re-deployed.

5.1.3 Particle Flux Measurements with Drifting Particle Traps

(J. Langer)

In addition to moored sediment traps, drifting trap experiments were carried out to determine particulate carbon flux that originates directly from the euphotic zone. These rates were interpreted in the context of measurements of the standing stock and production rates of the plankton community in the euphotic zone.

To study particle flux below the euphotic zone, two surface-tethered particle interceptor arrays were deployed in the vicinity of the ESTOC station, carrying three traps at 200, 300 and 500 m depth (Trap III, Fig. 12). The traps were attached to a surface buoy carrying an ARGOS transmitter and a Radar reflector. The main buoyancy was located at about 30 m depth to avoid the wind-induced EKMAN layer.

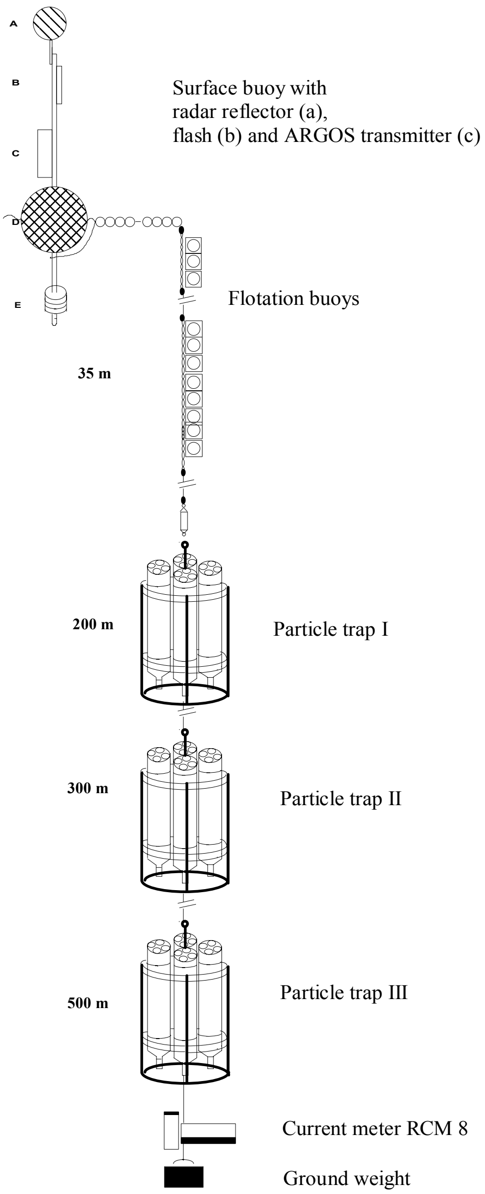

Fig. 12: Drifter carrying traps 200, 300 and 500 m depth.

The drifting trap were deployed two times. During all deployment periods the traps drifted south with a declination towards east (Tab. 4).

Tab. 4: Details of the drifting traps deployed during M45/1.

Drifter	Deployment period	Hours deployed	Deployment position	Recovery position
DT_1	25.05. - 28.05.	48	29°10,4 N 015°43,9 W	29°05,5 N 015°31,4 W
DT_2	28.05. - 30.05.	48	29°05,3 N 015°31,4 W	29°04,9 N 015°15,5 W

5.1.4 Particle Camera System

(V. Ratmeyer)

A high-resolution photographic camera system was used to measure the vertical particle concentration, size distribution and aggregate composition in the water column (RATMEYER AND WEFER, 1996). It was designed and improved in consideration of similar systems used by HONJO et al. (1984), ASPER (1987) and LAMPITT (1985). 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 even in areas or depths with high lateral transport.

The aim of deployment to different depths down to 3600 m during M45/1 was to observe the deep-sea particle population and possible lateral advection of particle clouds from the continental shelf towards the open ocean.

For measuring particle size and sinking speed, a Photosea camera was electronically triggered via the ships wire. Instrument testing was successfully performed aboard RV METEOR.

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 therefore be done in Bremen.

5.1.5 DOMEST

(G. Meinecke, V. Ratmeyer, G. Ruhland, U. Rosiak, F. Druenert)

Main DOMEST Objectives for the M45/1 Cruise

The main objective of this cruise was to implement and to test parts of the sensor package proposed in the DOMEST project. On this cruise, the first sensor communication via acoustic modems should be tested. The sediment trap and the FSI-CTD/currentmeter were attached to the OHB micro controller PC (BC2) and in conjunction with the acoustic modem the first sensor client were built. These sensors were implemented in the moored sensor unit (MSU), one of the major moorings in the DOMEST scenario (Fig. 13). It should be tested to obtain scientific data on request via OrbComm satellite link / SATEL (Pocket radio link for short distances) and acoustic underwater communication.

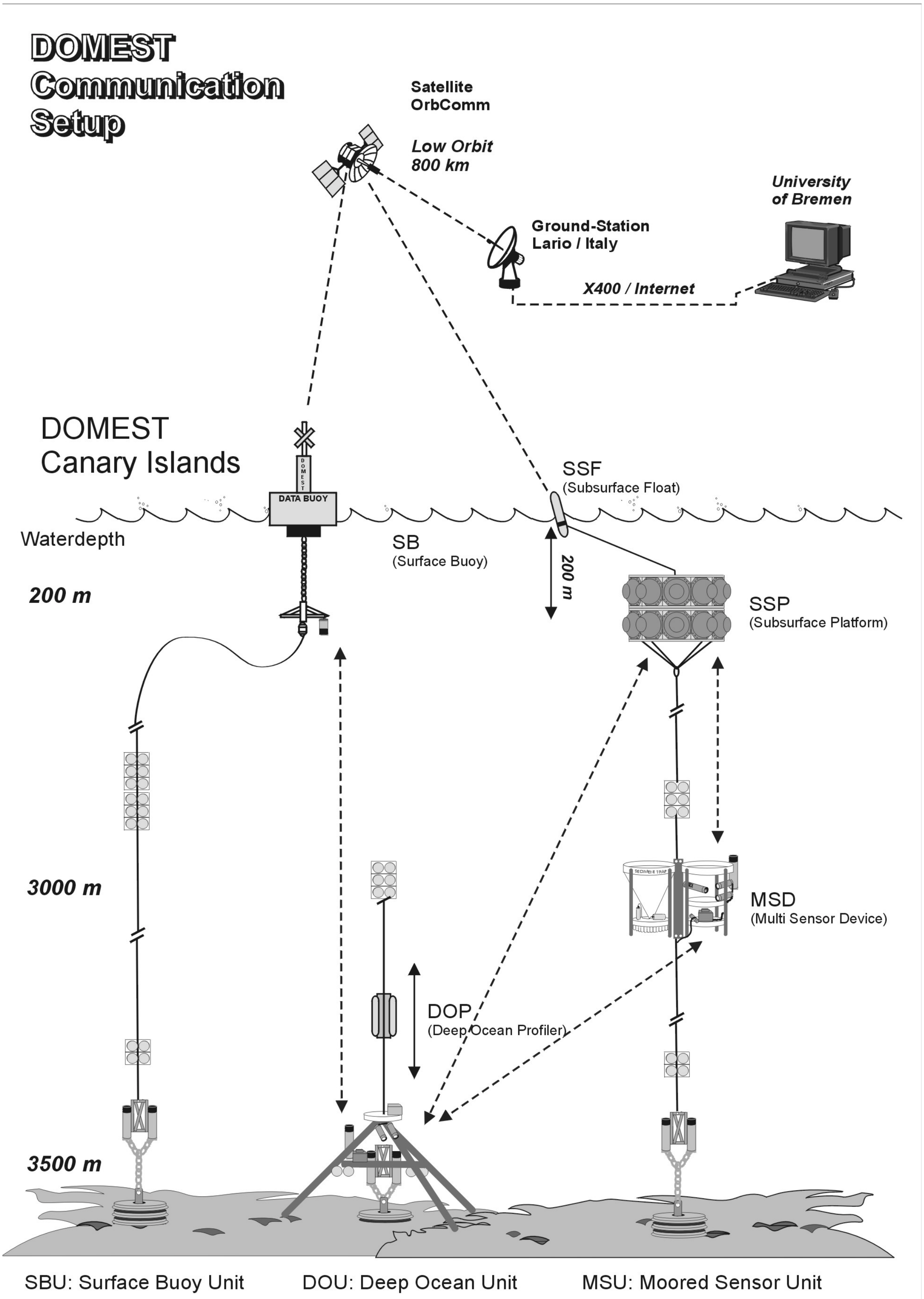

Fig. 13: Communication setup and general design of DOMEST moorings and equipment.

Test equipment

For testing an ORCA Deck Unit is used in conjunction with an FFT-Spectrogram Software package. This software is running on a separate PC, which itself is connected via an DAT-Recorder to the line-socket of the Deck Unit. While the deck unit is transmitting a signal as an acoustic data stream into the Ocean, this signal is displayed in real time in the FFT-software on the monitor PC in the Lab. The same happens with

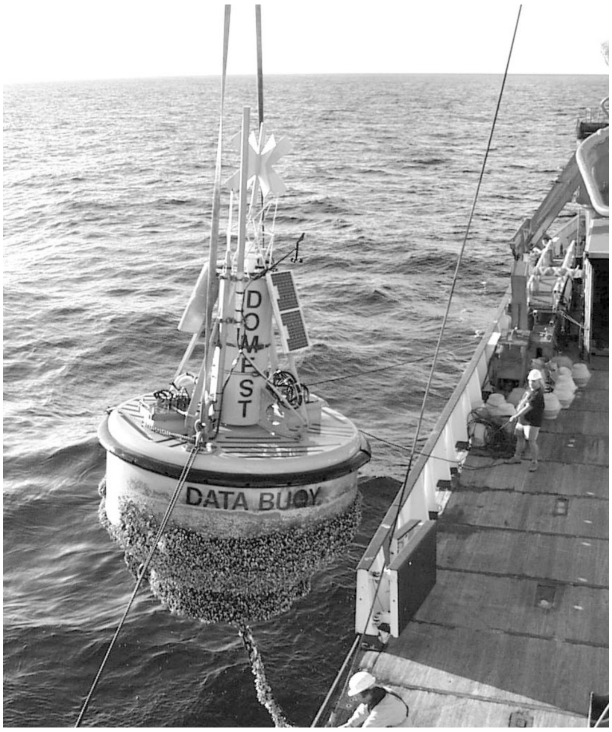

Fig. 14: DOMEST surface buoy during recovery. Visible is the intense biofouling on the subsurface of the buoys hull.

Fig. 15: Intense biofouling at the remote transducer head and at the 25 m chain of the DOMEST surface buoy.

each sound and noise in the water column. If a signal is coming back from an acoustic client - moored deep in the ocean - and is received by the transducer and passes through the Deck Unit, it will be displayed in the FFT-software on the monitor PC and heard as a sound from the PC speakers. With growing experiences one has the ability to analyse the transmitted signals - optically displayed as spectrograms on the monitor PC and acoustically monitored at the Deck Unit in order to separate different underwater clients or to analyse possible failure sources. Both, the DAT-Recorder and also the FFT-software have the ability to save all the communication, either as WAV-files on hard disk or as digital sound file on the DAT Tape. This equipment has been used with great success from the beginning of the DOMEST project.

Maintenance of the Surface Buoy Unit (SBU)

During the M42/4 cruise of the METEOR, the DOMEST surface buoy was deployed near the ESTOC site. Unfortunately, after a period of three months the buoy stopped transmitting tracking data. The main task during the M45/1 cruise was to maintain the surface buoy. Instead of the buoy, 24 glass spheres were attached to the steel cable - the uppermost part of the mooring line. The buoy, in addition to the attached 25 m chain and transducer head, was recovered without any problems and was placed on the main deck of METEOR. The buoy was in good condition, but showed intense biofouling with mussels and crabs on the buoy (Fig. 14), chain and also on the transducer head (Fig. 15). The cable from the remote transducer was cut by a fishing line. The lid from the electronic pocket was removed and it was obvious that the electronic pocket was flooded due to an ineffective rubber sealing. The electronic rack was rebuilt and attached to the buoy and the electronic pocket was sealed. In addition, a Spare OrbComm unit - completely independent from the buoys electronic - was placed at the central mast on the buoy in order to transmit tracking data on a daily base. Finally, the buoy was moored again by removing the glass spheres and attaching the buoy to the steel cable.

Deployment of Moored Sensor Unit (MSU)

The Deep Ocean Bottom Station was moored during the M42/4 cruise in 3.600 m water depth with onboard installed acoustic modem and BC2 controller. For servicing and for testing, the DOBS was recovered successfully. The platform itself and the electronic were in good condition.

For the next steps in device testing, the frame of the platform was used as the Sub Surface Platform (SSP, comp. Fig. 13) inside the moored sensor unit (MSU). The original electronic of the DOBS was implemented in a small separate test frame, in order to use the DOBS as a moored under water client in the deepest part of the MSU, with the advantage to save one mooring deployment (Deep Ocean Unit). In the middle part of the MSU the Multi Sensor Device (MSD) with implemented sediment trap, FSI CTD, acoustic modem and micro controller were placed. At the top of the MSU, the Sub Surface Platform equipped with acoustic modem and micro controller was placed. In this configuration the MSU consists of three independent under water clients - SSP - MSD - DOBS. The mooring was deployed beside the surface buoy mooring in order to run the communication tests.

Acoustic field test of SBU, DOBS and MSU

With the deployed surface buoy SBU, DOBS and MSU on site, the next tasks were performed. The METEOR was stationed near both moorings, in order to monitor the underwater acoustics running between SBU, DOBS and MSU. The buoy was remote- controlled via the packed radio link SATEL for the next tests. This radio link was completely comparable to the OrbComm satellite link, talking on software architecture basis. Because it is completly independent from satellite presence, it is a direct and easy to use online bidirectional test link. Now, the same test has been performed as on former tests. From aboard the METEOR, the buoy was programmed to ask the DOBS acoustically for status data and afterwards the acoustic clients from SSP and from MSD. Finally, the sediment trap and also the FSI CTD were asked for data. All these data were transmitted acoustically to the buoy and from there via SATEL radio link to the METEOR with great success. All tests have been monitored with the deck unit and stored with the DAT tape onboard the METEOR.

Final field test of SBU and DOBS – The Acoustic-Satellite Link

With the deployed moorings on site the final tests were performed. The former tests were done with an BC2 controller - attached to the deck unit - from aboard the METEOR and via SATEL radio link. Finally, we started to run several data requests via satellite communication. The communication via the mobile OrbComm transceiver onboard the METEOR have worked well. It was no problem to get test messages and status data from the DOBS, deployed in 3.500 m water depth. The pathway for the communication runs from the METEOR via OrbComm satellite to Italy, via satellite back to the SBU, acoustically through the water column to the DOBS, read out status data, send these data acoustically back to the buoy, via satellite to Italy and via satellite back to the METEOR. It was the first successful close-loop test - with data request from ship via satellite into the deep sea and back via satellite to the ship - performed within less than 8 minutes.

The MSU mooring was recovered at the end of these tests and the frame of the SSP was prepared for re-deployment with the installed DOBS electronic. After finishing the instrumentation, the DOBS platform - with attached 1 tons anchor weight below the platform - was lowered down to 3.580 m water depth via the ships wire and stopped 50 m above the seafloor. Now, the second pair of acoustic release – mounted between DOBS and ships wire at the top of the DOBS - were released and the DOBS settled down to the seafloor and was left in place till October 1999 for the M45/5 cruise.

5.1.6 Deep Ocean Profiler (DOP)

(C. Waldmann, M. Bergenthal, W. Metzler)

During METEOR cruise M45/1 further tests of the deep sea profiling instrument carrier DOP have been carried out. This second series of *in-situ* tests was a necessary intermediate steps to evaluate the function of the complete system under field conditions. In preparing the cruise several laboratory tests had been undertaken. Due to the complexity of the system, however, these tests only allow to check the performance of single modules.

The profiler consists of three major mechanical building blocks, the hydraulic unit housed in a highly rigid ceramic tube, the electronics unit housed in a glass tube and the two floatation material blocks (Fig. 16). These blocks predominantly determine the overall weight and volume of the system and in the end the dynamical performance i.e. speed and depth range. The mechanical design of the basic building blocks has been approved and remained unchanged compared to the former tests.

The sea trials on this cruise focus on the control devices and the housekeeping sensors. The following items describe the test program:

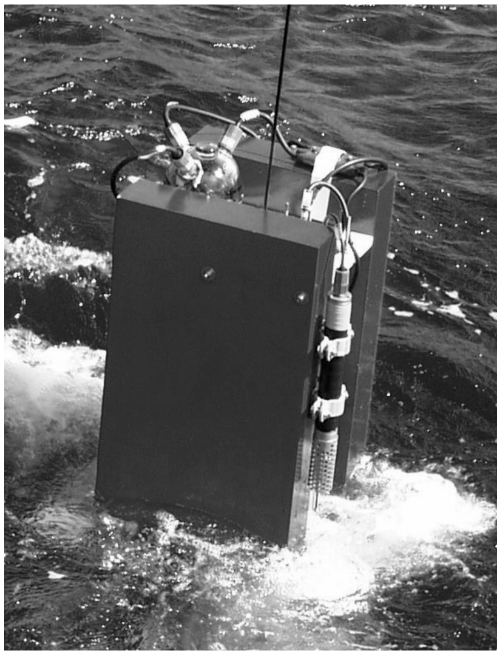

Fig. 16: The deep sea profiler DOP during deployment from METEOR.

- Test the performance of the new implemented PC based micro controller system
- Evaluate the housekeeping sensors i.e. motor current, internal pressure sensor (Filling level of the oil bladder) and the external pressure sensor
- Test the data transfer with the new adapted ME-CTD system
- Confirm the function of the hydraulic system under high pressure conditions
- Test the software by passing through different operation states

The *in-situ* testing of the profiler is a rather time consuming task. The typical deployment time interval is 8 h for two cycles in 2000 m depth over a depth range of 300 m. To get the best results during these tests the controller system is operating under a real time kernel that allows recording data under independent tasks. Therefore a minimal amount of data is available even if a part of the system malfunctions. This makes a localisation of possible failure sources easier.

Test sequence

The test sequence is determined by the balancing of the weight of the profiler and follows a uniform procedure:

1. Rough adjustment of the weight at the sea surface.
2. Deployment in shallow depth (~ 200 m) to measure the speed for both directions of motion (up and down).
3. Calculating the excessive weight from different speeds and fine trimming of the system.

Due to the different compressibility of the profiler compared to seawater and the density change due to salinity and temperature variations one has to add some weight to balance the system for greater depths (~ 100 g for 200 m).

The system was deployed eight times. The last test was performed in a depth interval of 1600 to 1800 m. In this last test all functions including the data acquisition from the ME CTD has been tested successfully and valuable data were delivered.

Results of the tests

Hydraulic system: The combination of the chosen motor with the high pressure pump proved to be working satisfactory in all test. The pump duration for pumping out an amount of 2 l of oil against a pressure of 200 bar was 40 min. The motor current and the flow rate were within the specifications, given by the manufacturer. The flow reduction vent which was designed to reduce the re-flow rate of the oil from the external bladder (under the influence of the high pressure difference) had to be opened for about 100 s to let the 2 l of oil back in the system. We do not expect a major change of this time duration under higher pressures. This time interval can be controlled to adjust flow of the oil volume to 20 ml. This value is of sufficient accuracy for this application.

The internal pressure sensor had enough resolution to control the flow in and out of the ceramic cylinder. During the tests it was detected that the sensor showed a strong hysteresis, which might cause malfunctions in long term operations. A more reliable system has to be acquired for future tests.

The propulsion of the profiler results from a buoyancy change. The maximum pumping volume of oil is 3 l. Accordingly one achieves a maximum propulsion force of 1.5 kg. With 2 l pumped we achieved an approximate speed of 15 cm/s for both directions of motion.

Electronic unit: The central component of the electronic unit is the micro controller. For this system it is necessary to have highly efficient power down modi available for long term operations. In contrast, when the system is powered up it should be powerful enough to control the different tasks. Therefore it was decided to test a PC based micro controller system that has been on the market for one year. The system proved to be versatile and easy programmable. Additionally it is possible to use standard mass storage devices like hard disks or RAM-disks for storing scientific data and housekeeping data. However, during the tests it was found out that the power down modi were not be supported as had been expected. Therefore, longer test runs for instance deployment as a moored system were not possible. This problem will be addressed in future tests.

The performance tests showed that the typical load on the CPU was in the range of 30 %. That means that for instance more complex missions could be supported and additional sensors could be adapted easily. The ME-CTD that currently delivers the scientific data is sending the data at a rate of 4 data sets per second. In the following graphs (Fig. 17, 18) an example measurement is displayed. Two successive temperature profiles were taken with the CTD mounted on the profiler. Due to the monotonic and smooth motion of the profiler very high quality data are recorded.

The following Fig. shows a time series plot of the built-in pressure sensor. Again, the smooth and monotonic motion can be seen. The gradient of the curve gives the speed of the profiler. The speed for the up and down motion differ by 2 cm/s at an absolute speed of 15 cm/s.

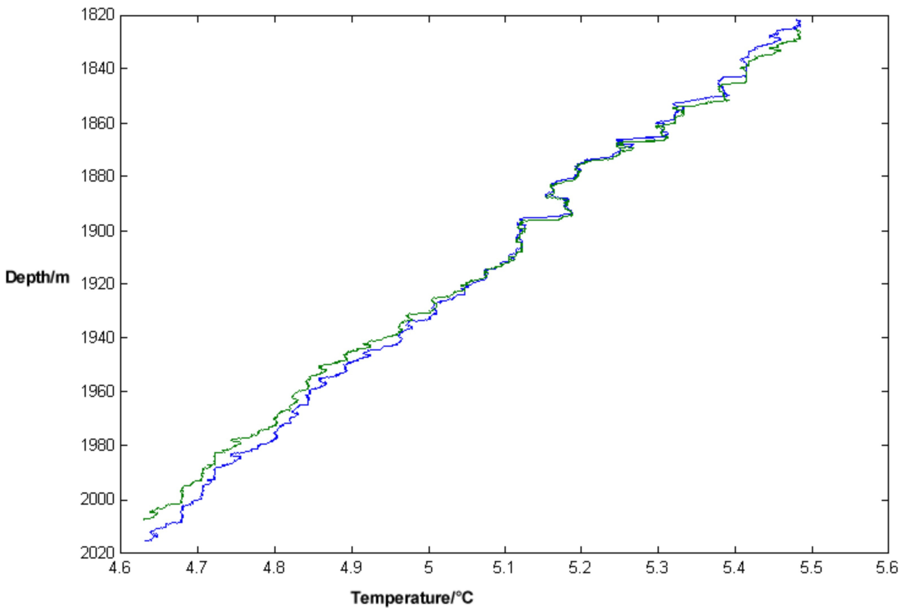

Fig. 17: Pressure measurement taken with the external pressure sensor of DOP showing the smooth motion of the profiler.

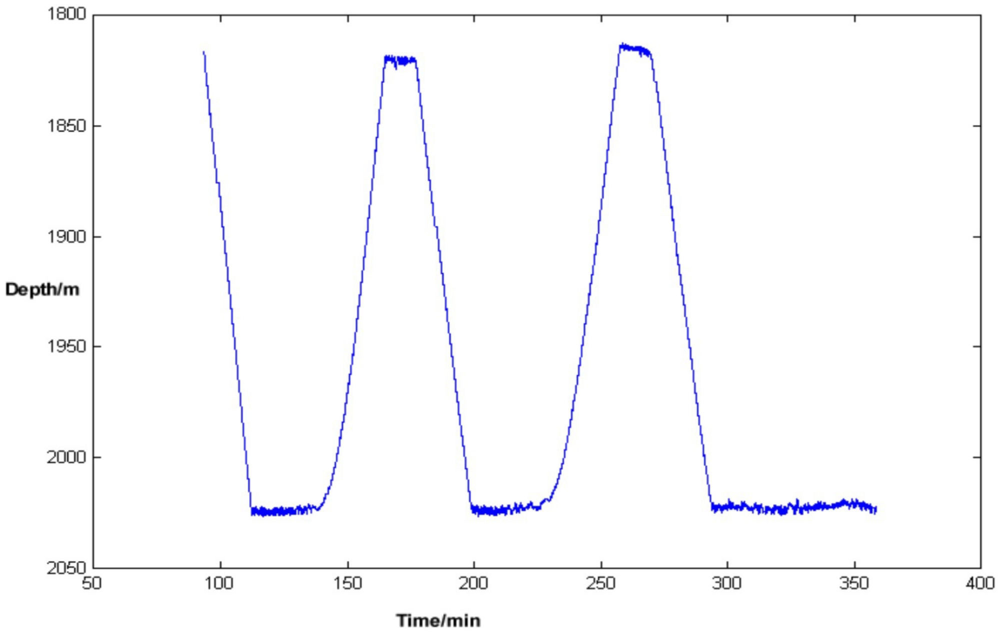

Fig. 18: Two successive temperature profiles recorded by the ME-CTD sensor showing the high reproducibility of the temperature measurement.

5.1.7 Field Tests of the Optical Density Sensor OPRA

(C. Waldmann, M. Bergenthal, W. Metzler)

The *in-situ* going optical density sensor OPRA (Fig. 19) that was developed recently at the University of Bremen (Centre for Marine Environmental Sciences, Marum) was deployed four times during METEOR cruise M45/1. The deployment depths were between 150 m and 1000 m. The principle of the sensor is based on the measurement of the refractive index of seawater. Due to the close relationship between

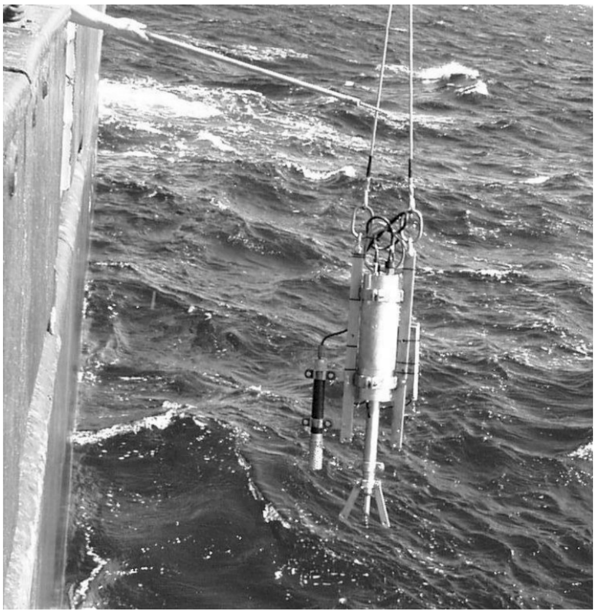

Fig. 19: The sensor OPRA together with a CTD during deployment from board RV METEOR.

density and refractive index the operational sensor will open up new fields of investigations primarily in the field of turbulence processes. Other features of the sensor are:

- High sampling speed due to the small measuring volume.
- High resolution in a measuring range going from freshwater to high saline waters.
- Easier calibration procedure compared to CTD systems.
- Probably low biofouling on the sensor surfaces and therefore high stability.

For the purpose of evaluating the sensor a parallel measurement of the density with a CTD system was made. A first quick view at the data on board the RV METEOR showed the high correlation between density and refractive index. Without any further correction that may be due to an explicit temperature dependence it will be possible to calculate the density from refractive index with an accuracy of the order of 10^{-4}.

In laboratory tests that were done before the cruise a pressure effect of the refractive index sensor was detected. After a first evaluation of the *in-situ* results this effect is only influencing the measurements in the surface layer down to 40 m. This gives a valuable hint to the solution of this technical problem.

In the following graph the result of a parallel measurement of the density with the optical sensor OPRA and the electrical sensor is displayed (Fig. 20).

5.1.8 Marine Chemistry

(C. v. Oppen, A. Deeken, O. Morisse)

The biogeochemical cycle of trace metals is controlled to a large extent by particle-water interactions like adsorption-desorption processes or active incorporation of trace metals by marine organisms. Marine particles are classified into large fast sinking particles responsible for the downward transport of trace metals and the bulk of small particles (< 0,4 µm) known as suspended particulate matter (SPM) with very low sinking velocities. Due to much longer residence times in the water column and large surface areas SPM mainly accounts for particle-water interactions of trace metals. The actual mechanisms of these processes, however, are not yet known. The presence of organic material may have an important impact

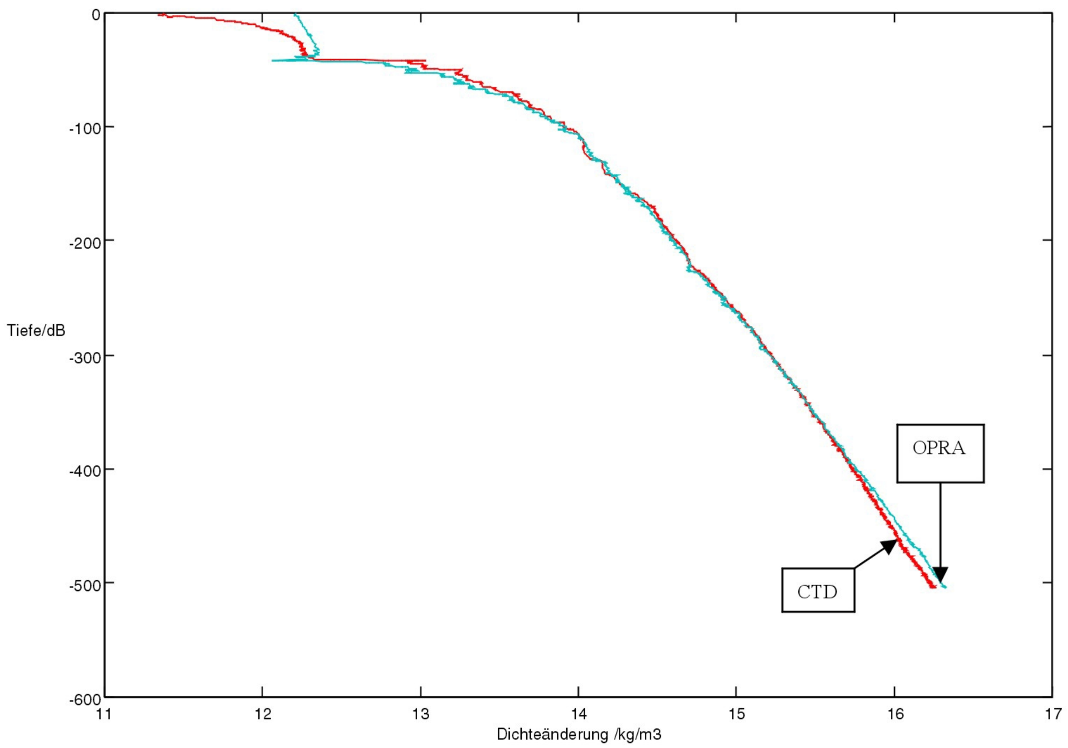

Fig. 20: Parallel in-situ measurement of the density with the optical sensor OPRA (grey) and a CTD (black).

since organic substances often provide good bonding sites for metals due to the variety of their functional groups.

Samples for dissolved trace metals were collected by means of pre-cleaned 12 l Go-Flo bottles mounted to a rosette system. For the collection of particulate matter in-situ pumps were used and operated from an all-plastic hydrowire.

To reduce risk of contamination, sample processing on-board was done under a class 100 clean bench inside a clean-air laboratory container.

On this cruise our main interest was set on sampling SPM at ESTOC by means of in-situ pumps for the determination of both trace metals and organic carbon. Different kinds of membranes were used for the determination of trace metals and organic carbon, respectively. For trace metal analyses seawater was filtered through polycarbonate membranes (142 mm, 0.4 □m pore size, Nucleopore), whereas samples for the determination of organic carbon were collected with Quarz Microfibre Filters (QM-A, 142 mm, Whatman). Subsequent analyses will be performed in our lab onshore.

Samples for dissolved and particulate trace metals were also obtained from one station in the Golf of Cadiz at 36° 20'N and 8° W. Detecting the characteristic trace metal signal of the Mediterranean Outflow plume for both the dissolved and particulate phase is of interest, since our stations north of the Canary Islands are still influenced by the intrusion of Mediterranean Water at intermediate depth (1000 m – 1300 m). In the Golf of Cadiz we find high dissolved aluminium concentrations (~ 69 nM) at depth of the Mediterranean Outflow plume which agree well with reported dissolved aluminium concentrations in the literature. Other dissolved trace metals as well as the particulate samples will be analysed onshore.

Finally, we recovered our two multi-pump systems (deployed in the ESTOC mooring CI10 from October 98 until June 99) and also successfully deployed three new multi-pump systems in the following mooring CI11. Pumps were equipped with polycarbonate membranes for the collection of particulate matter as well as with an *in-situ* pre-concentration system for dissolved trace metals.