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REPORT AND PRELIMINARY RESULTS OF METEOR CRUISE M45/1 MALAGA (SPAIN) - LISSABON (PORTUGAL)

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Meteor Cruise M45-1 (Malaga - Las Palmas)

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2. INTRODUCTION

2.1 Project CANIGO / ESTOC

The Canary Islands region occupies a key position with respect to biogeochemical cycles, with the zonal transition from oligotrophic to nutrient-rich waters and the contribution of Saharan dust to the particle flux. The goal of CANIGO Subproject 3 is to determine the influence of coastal upwelling and Saharan dust on the magnitude and composition of particle flux in the Canary region, and to investigate how this influence varied through the last glacial and interglacial period. According to this the Subproject 3 of CANIGO is organized in two main work packages. The main aim of the first work package is to quantify particle flux and to determine its composition on seasonal and interannual time scales along a zonal transect at 29°N. The main goal of the second work package is to study the variability of accumulation rates of environmentally sensitive parameters and atmospheric dust through the last glacial-interglacial cycle across an upwelling margin. This work package will use the data from the water column in an actualistic approach to decipher the particle flux history back to 250,000 years.

Particle flux will be investigated with sediment trap moorings (ESTOC ("European Station for Time Series in the Ocean - Canary Islands, CI" and LP ("La Palma mooring")) on a zonal transect from the shelf to the outer oligotrophic region of the Canary archipelago (29°N transect). The ESTOC-mooring contains in-situ pumps for sampling the water column for trace metals and two or three sediment traps. Sampling periods ranges from one to two weeks. The particulate material collected will be analysed to determine total fluxes of organic, anorganic components and for species composition of the planktonic organisms (pteropods, foraminifera, radiolaria, coccolithophorids, and diatoms). The objective of these studies is to identify signals of seasonal variations in those components, which play an important role in the sediment formation process. The results of these investigations will form a basis for the reconstruction of paleocurrent systems and paleoproduction of the sediments. Vertical profiles from sea surface till bottom will be recorded with the high resolution particle camera system ParCa at pre-defined locations, in order to measure the particle concentration along the transect.

For the study of selected marine trace elements vertical profiles of dissolved and particle-bound elements will be recorded:

1. To improve the seasonal and vertical resolution of our profiles at ESTOC and La Palma.
2. In the Golf of Cadiz to evaluate the possible impact of mediterranean outflow water on trace element concentrations at ESTOC.

2.2 Project DOMEST

The aim of the project DOMEST is the development of a moored sensor network in the deep sea. The advanced sensors will provide high-resolution data on particle fluxes and element concentrations in the open ocean and can be accessed from land via satellite and acoustic transmission. Communication under water will be performed through a bi-directional acoustic high-speed telemetry. Above water, a satellite network will establish the data transport between the moored system and a land based ground station in Italy. The system will be deployed at 3600 m water depth over a maximum duration of one year. With DOMEST a remotely controlled measurement of element and particle transport in the deep sea will be possible. Importantly, remote control includes access on a variety of data without recovering the sensors from the deep ocean. These possibilities allow an advanced sampling and probing of parameters depending on various environmental parameters, such as satellite derived ocean colour or particle input during dust storms. Such an "interactive" measurement of relevant parameters will enhance the understanding of transport processes from the surface to the deep ocean and allows a more detailed reconstruction of paleoclimatic changes.

Within DOMEST three subsystems will be established and used:

1. Deep-sea mooring with several measurement devices:
   Moored Sensor Unit (MSU) with Subsurface Platform (SSP) and Multi Sensor Device (MSD)
2. Parallel mooring with surface buoy:
   Surface Buoy Unit (SBU)
3. Deep Ocean Bottom Station:
   Deep Ocean Bottom Station (DOBS) with autonomous profiling Deep Ocean Profiler (DOP)

3. RESEARCH PROGRAM

The research activities during the M45/1 cruise were related to the scientific programs CANIGO and DOMEST.

At the beginning of this cruise, a condensed geological sampling program should be conducted in the Gulf of Cadiz (Figure 1). The PARASOUND echosounder system and the HYDROSWEEP multi-beam echosounder should be used on site as a proven tool to find suitable locations of sampling sites. The sampling will be done with gravity- and multi-corer. In addition to geological sampling, water column sampling will be conducted with single-pumps.

Near the Canary Islands, the scientific work will focus on the BMBF funded project DOMEST (Figure 2). First of all, the permanent surface buoy need to be maintained. Afterwards, acoustic data-transmission into the deep ocean will be tested again, as well as the connection to a satellite communication network. New devices will be tested for their functioning on board, in the deep ocean and connected to the acoustic communication line.

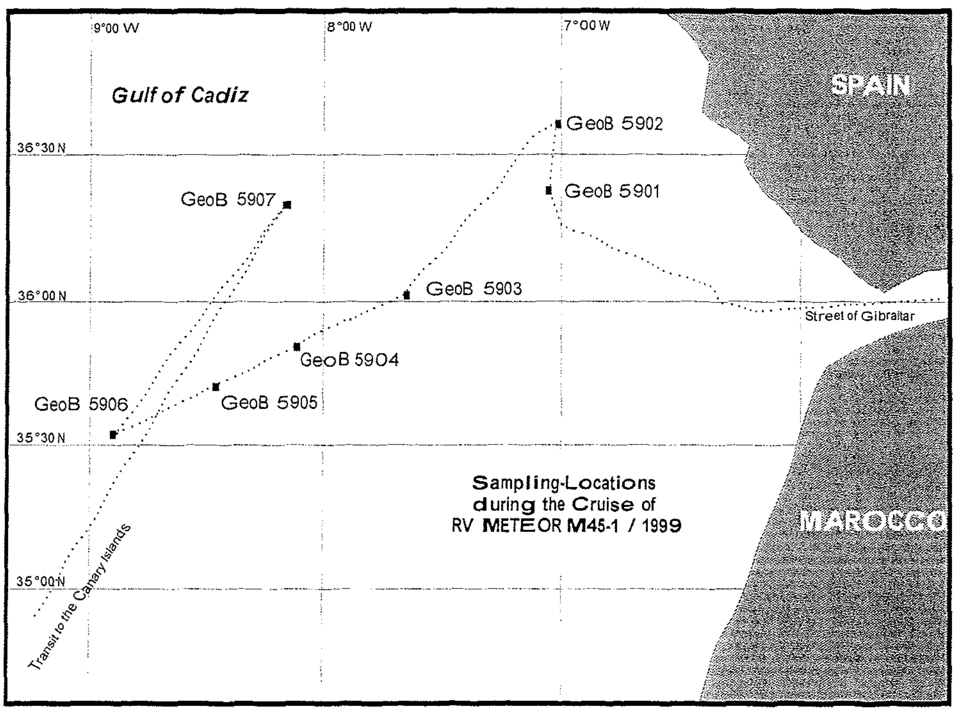

Fig. 1: Cruise track and sampling locations in the Gulf of Cadiz.

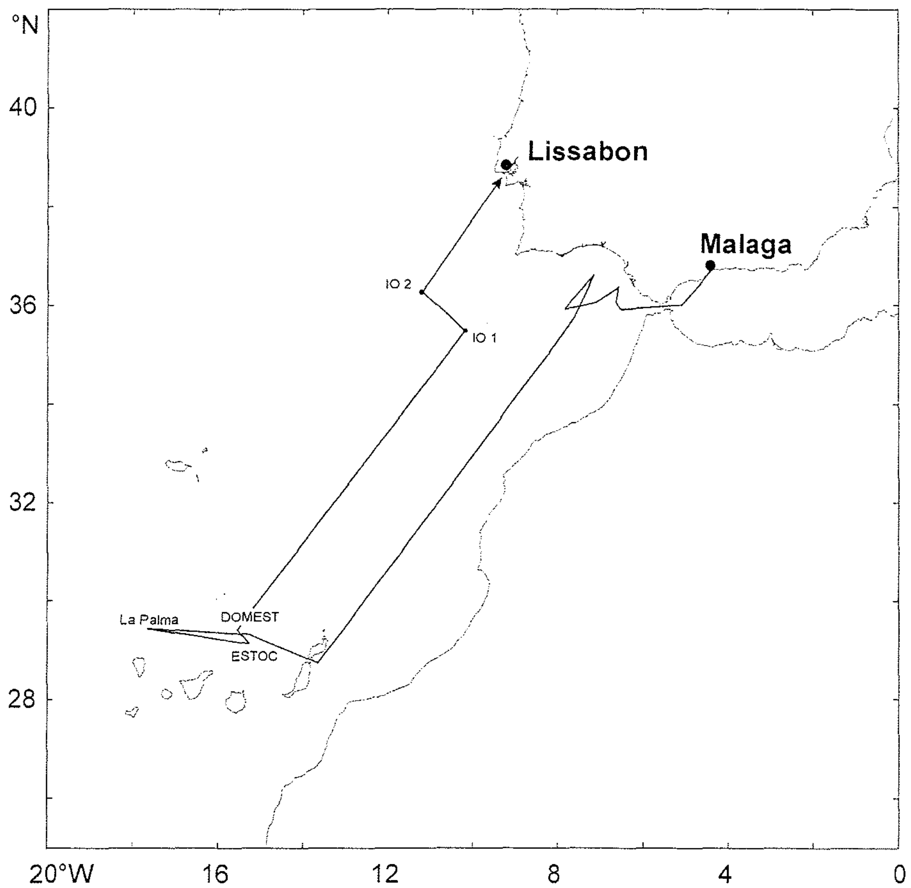

Fig. 2: Cruise track and working locations during RV Meteor cruise M45/1.

Within the framework of the deep-sea device testing programme DOMEST the following work is planned:

1. Service of the permanent surface buoy (SBU). Test of satellite telemetry via OrbComm satellites. Controlling of the GPS-data. Programming and interface tests between the under water (UW) and satellite communication. Test of UW communication via the top buoy as master unit.

2. Test of UW communication from the ship to devices and also on ships wire down to 3500 m water depth.

3. Deployment of MSU with UW-Platform (SSP, 200 - 500 m water depth with the Multi Sensor Device (3000 m water depth) and the unit for the Deep Ocean Bottom Station (DOBS, 3500 m water depth). Location of the anchor position of MSU and location in the water column via SSP position.

4. Communication with acoustic modems in SSP, MSD, DOBS and SBU. Test of the total communication, including the satellite link.
5. Test of Deep Ocean Profiler (DOP) and the optical Refractometer (OPRA).

Parallel to the DOMEST activities, scientific work related to the EU funded CANIGO project will be done. Particle flux will be investigated by servicing two sediment trap moorings (CI mooring" and LP mooring) on a zonal transect from the shelf to the outer oligotrophic region of the Canary archipelago. In addition to sediment traps the ESTOC-mooring contains in-situ pumps for sampling the water column for trace metals.

4. SUMMARIZED CRUISE REPORT

The research activities during the METEOR cruise M45/1, which started 19th of May in Malaga, were related to the scientific programs CANIGO/ESTOC and DOMEST. Both projects have a different focus and working areas. The DOMEST project concentrates on marine technology and data transmission, mainly tested in the Canary Island region. The CANIGO/ESTOC project concentrates on seafloor and water probing. Samples during this cruise were taken in the Gulf of Cadiz and in the Canary Island region.

At the beginning of this cruise, a condensed geological sampling program has been conducted during the first four days in the Gulf of Cadiz. The structures of the near-surface sediments, which reflect the effects of paleoceanographic and paleoclimatic variability in the sedimentation processes, has been continuously monitored at high resolution with the PARASOUND echosounder system. In addition a survey of the general morphologic setting was achieved by the swath bathymetry system HYDROSWEEP. Both acoustic board systems were used on site as a proven tool to find suitable locations for 7 sampling sites on an SW-transect through the Gulf of Cadiz. On these sites sediments samples were taken with gravity and multi-corer. The sites are located on the outer shelf (500 and 580 m water depth) and on the continental slope in different depths down to 3029 m water depth. The final location GEOB 5907 was used to run the single-pump systems, in order to analyse the Mediterranean Outflow Water and to run the first test of the new designed optical Refractometer (OPRA). At the end of these tests the RV Meteor left the Gulf of Cadiz on Saturday the 22nd with destination Canary Islands.

Near the Canary Islands, the scientific work was focused on the national funded project DOMEST ("Data transmission in the ocean and technology for high resolution measurement of particle fluxes into the deep-sea"). The scientific work schedule started on the 25th of May at the DOMEST location (see Figure 2). First the permanent surface buoy had to be maintained. The satellite electronics were complete destroyed due to a leakage of the electronic cases. In addition to this, the transducer cable 30 m below the buoy has been cut by fishery activities. New devices like the integrated Multi Sensor Device (sediment trap, acoustic CTD and micro controller), the deep sea YoYo profiling vehicle, deep sea winch system and the optical Refractometer were tested for their functioning on board and in the deep ocean with great success.

Afterwards, acoustic data-transmission into the deep ocean were tested again, as well as the connection to the OrbComm satellite communication network. On this cruise is was possible to run the first complete “close loop test” of the communication line. Two underwater clients with scientific sensors has been installed before this test and each client was tested separately. From aboard the RV METEOR a request for CTD data (sensor was located in 2000 m water depth) was send via satellite to Italy, routed back via satellite to the surface buoy, transferred to the acoustic underwater modem and send into the deep sea as an acoustic data stream to the deep ocean bottom station (DOBS). From here the request passed through to the multi sensor device (MSD) acoustically, which itself asked the CTD sensor for data and send these data back to the surface buoy as an acoustic data stream. Here these data were transferred to the satellite transceiver and were send back via satellite to Italy. In Italy these data were routed back to the mobile satellite station aboard the RV METEOR. This complete test takes only 8 minutes from request to answer.

Parallel to the DOMEST activities, scientific work related to the EU funded CANIGO/ESTOC project has been done. The ESTOC sediment trap mooring was maintained and the La Palma mooring was recovered without replacement. In addition vertical profiles with the high resolution particle-camera system ParCa were recorded at defined locations, drifting sediment traps were used twice in the ESTOC region and intense water column sampling and probing with multi-pumps and a rosette watersampler has been done at ESTOC and DOMEST locations, performed by the marine chemistry working group. The scientific work was finished at the 4th of June and the RV METOR left the Canary island region with destination to the Portuguese Sound Sources Moorings IO1 and IO2 father in the north.

At the 6th of June, is was planned to recover the IO1 mooring. The recovery failed and the mooring could not be recovered due to a collapsed top buoyancy package of the mooring line. At the next day, the IO2 mooring was recovered without any problems and the scientific work for this cruise ends and the RV METEOR started its transit to Portugal. In the morning of the 8th of June the RV METEOR arrived in the harbour of Lissabon and a very successful scientific cruise found its end.

5. PRELIMINARY RESULTS

5.1 Sediment sampling with gravity- and multi corer

(Birgit Meyer-Schack)

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 (Table 1). The sediment cores has been cut into segments of 1 m each, described and stored at 4°C in the refrigerator storage rooms of RV 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 (Table 1). The core recovery was good, typically 10 to 12 tubes were filled, and cores of very good quality 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, coccolithophorides. The C_{org} samples were frozen immediately after sampling 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 were also collected for planktonic foraminiferal and coccolithophorides analysis. All the foraminifera and coccolithophoride samples were stored at 4° C. Mostly one large and/or one small core were frozen as archive material.

Tab. 1: 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

5.2 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 May 26th the ESTOC sediment trap mooring CI10 was recovered. The mooring 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 (Figure 3) at the same location. The CI11 mooring carries three sediment traps, two Aanderaa current meter and two particle pumps.

The La Palma sediment trap mooring LP 3 (Figure 4) was recovered on May 31st 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.

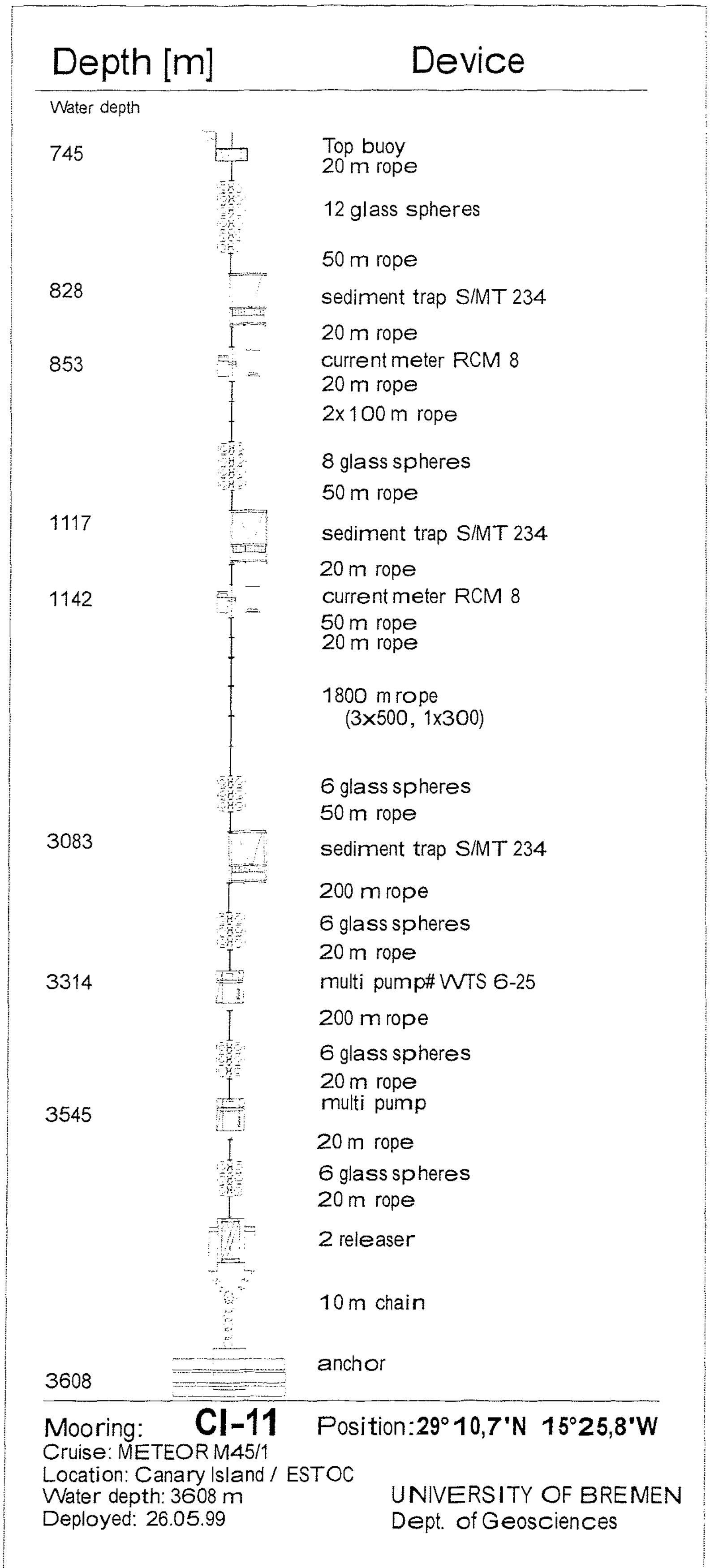

Fig. 3: Sediment trap mooring CI 11 deployed at ESTOC

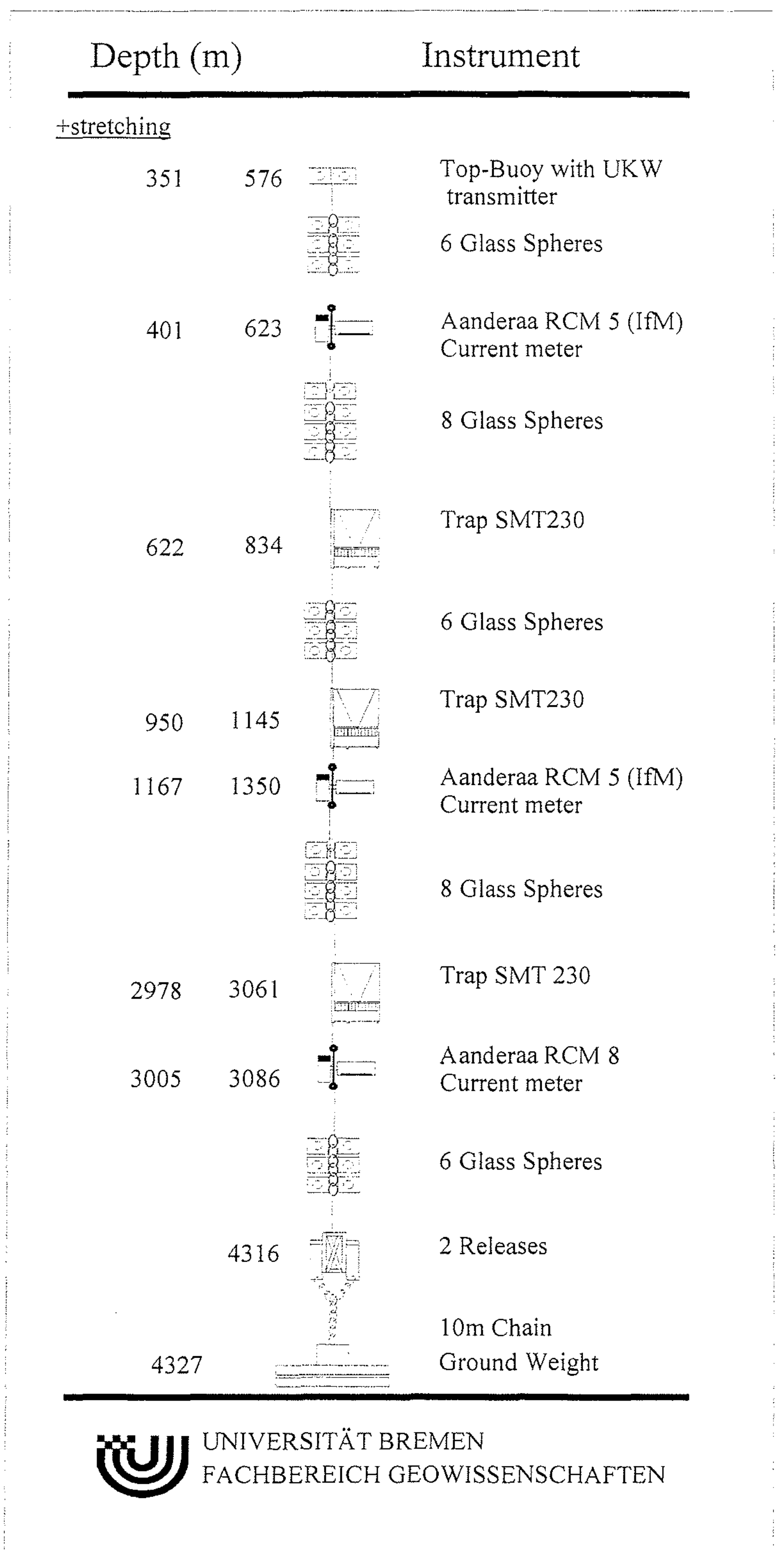

Fig. 4: Sediment trap mooring LP 3 recovered north of La Palma

5.3 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, Figure 5). The traps were attached to a surface buoy carrying an ARGOS transmitter and an Radar reflector. The main buoyancy was located at about 30 m depth to avoid the wind-induced EKMAN layer.

The drifting trap were deployed two times. During all deployment periods the traps drifted south with a declination towards east (Table 2).

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

Tab. 2: Details of the drifting traps deployed during M45/1.

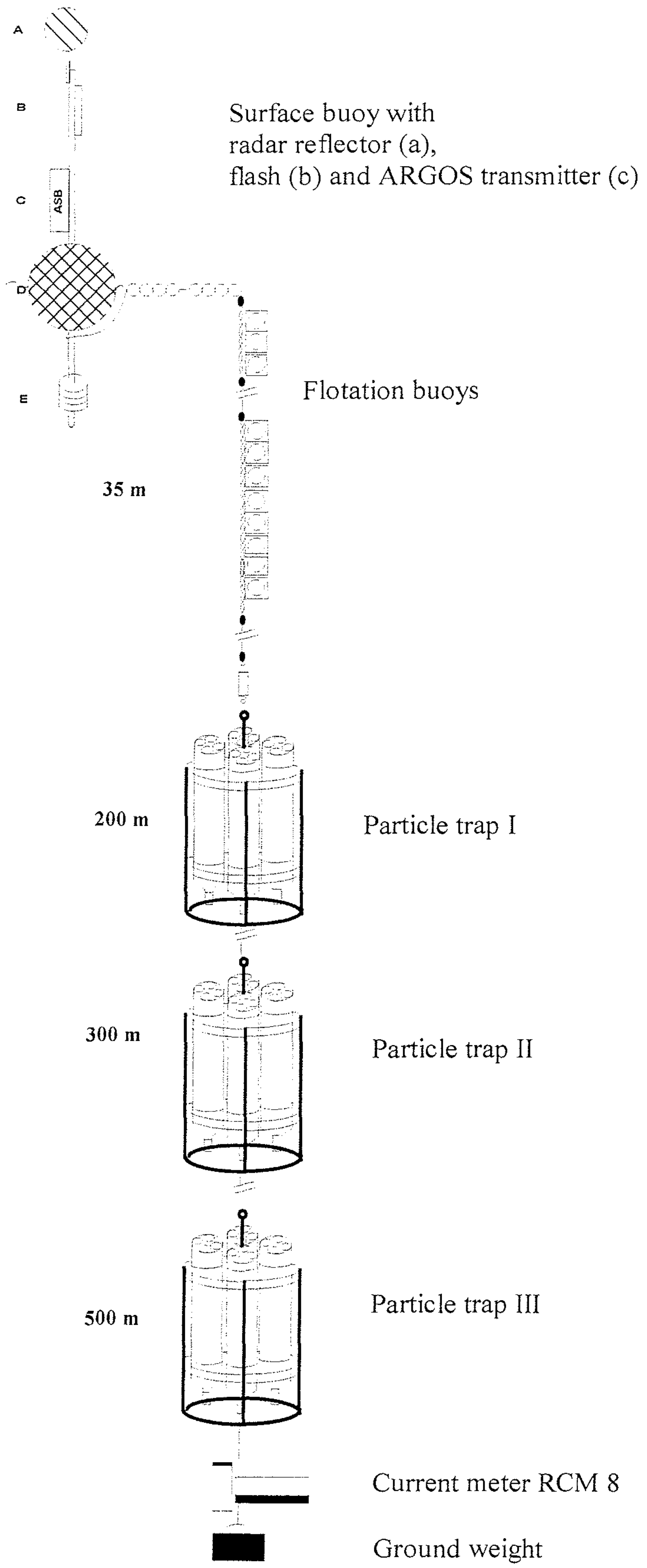

Fig. 5: Drifter carrying traps 200, 300 and 500 m depth.

5.4 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.

5.5 DOMEST

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

5.5.1 Main DOMEST Objectives for the M45-1 Cruise

The main objective on this cruise was to implement and to test parts of the sensor suit proposed in the DOMEST project. On this cruise, the first sensor communication via acoustic modems should be tested also. 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 was build. This sensor suit was implemented in the moored sensor unit (MSU), one of the major moorings in the DOMEST scenario (Figure 6).

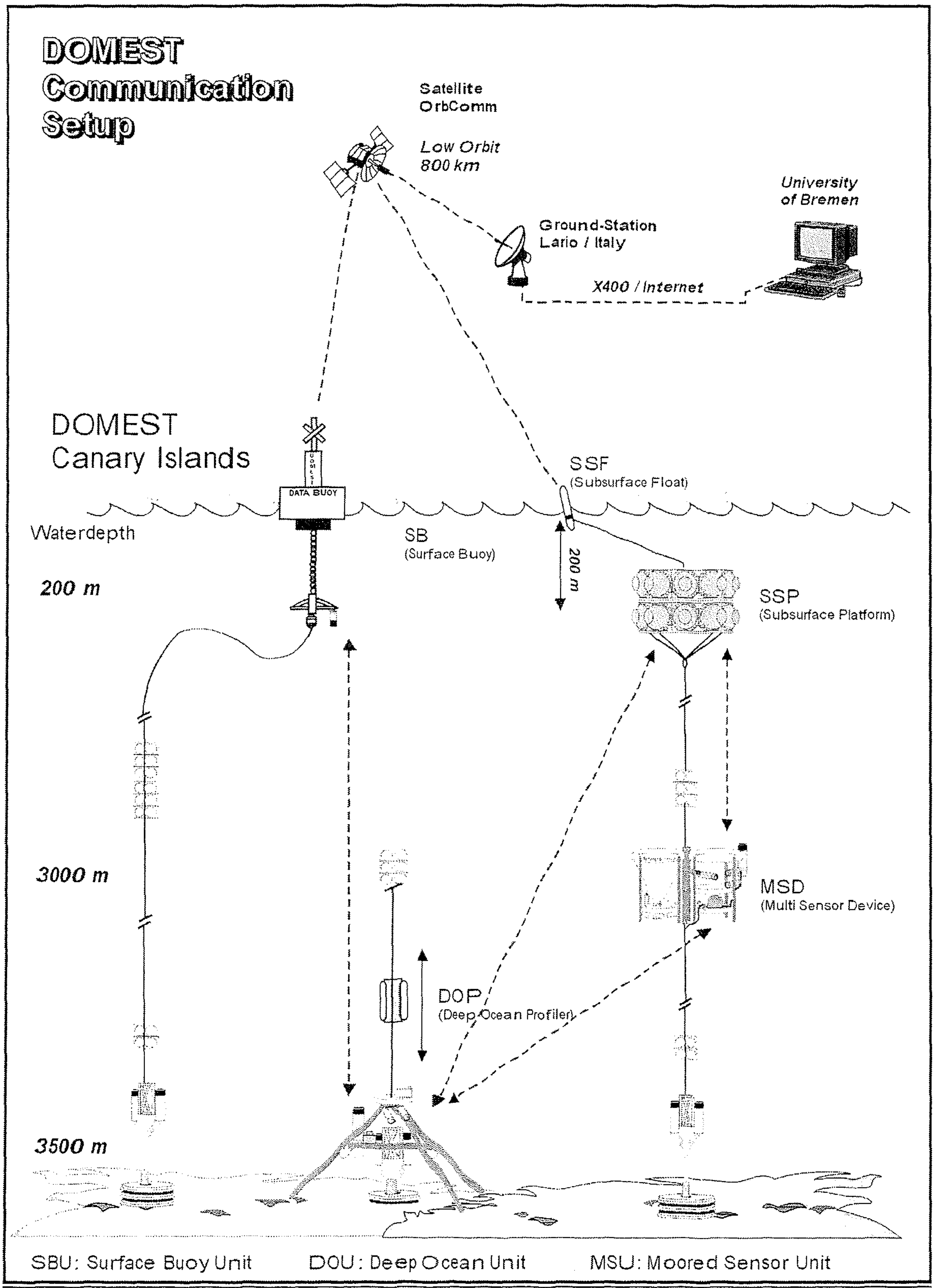

Fig. 6: Communication setup and general design of DOMEST moorings and equipment.

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

5.5.2 Test equipment

One of the biggest problems with underwater acoustic communication is to know what kind of communication take place inside the water column. If a communication fails during a test and the user don't have control about all kind of sounds in the water column, one can't decide why the communication fails - due to a real hardware problem or because the underwater client haven't heard the signal. For this reason for all acoustic tests the ORCA Deck Unit is used in conjunction with an FFT-Spectrogram Software package. This software is running on an 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 Laboratory. The same will happens with each sound and noise in the water column. If a signal is coming back from an acoustic client - moored deep in the ocean - received by the transducer and passes through the Deck Unit, this signal will be displayed in the FFT-software on the monitor PC and heard as a sound from the PC speakers. With growing experiences the user have 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.

5.5.3 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 month the buoy stopped transmitting tracking data. The main task during the M45-1 cruise was to maintain the surface buoy. Instead the buoy, 24 glass spheres were attached to the steel cable - the uppermost part of the mooring line. The buoy and the attached 25 m chain and transducer head, were recovered without any problems and were placed on the main deck of the Meteor. The buoy was in good condition, but shows intense biofouling with mussels and crabs on the buoy (Figure 7),

chain and also on the transducer head (Figure 8). The cable from the remote transducer was cut by a fishery 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.

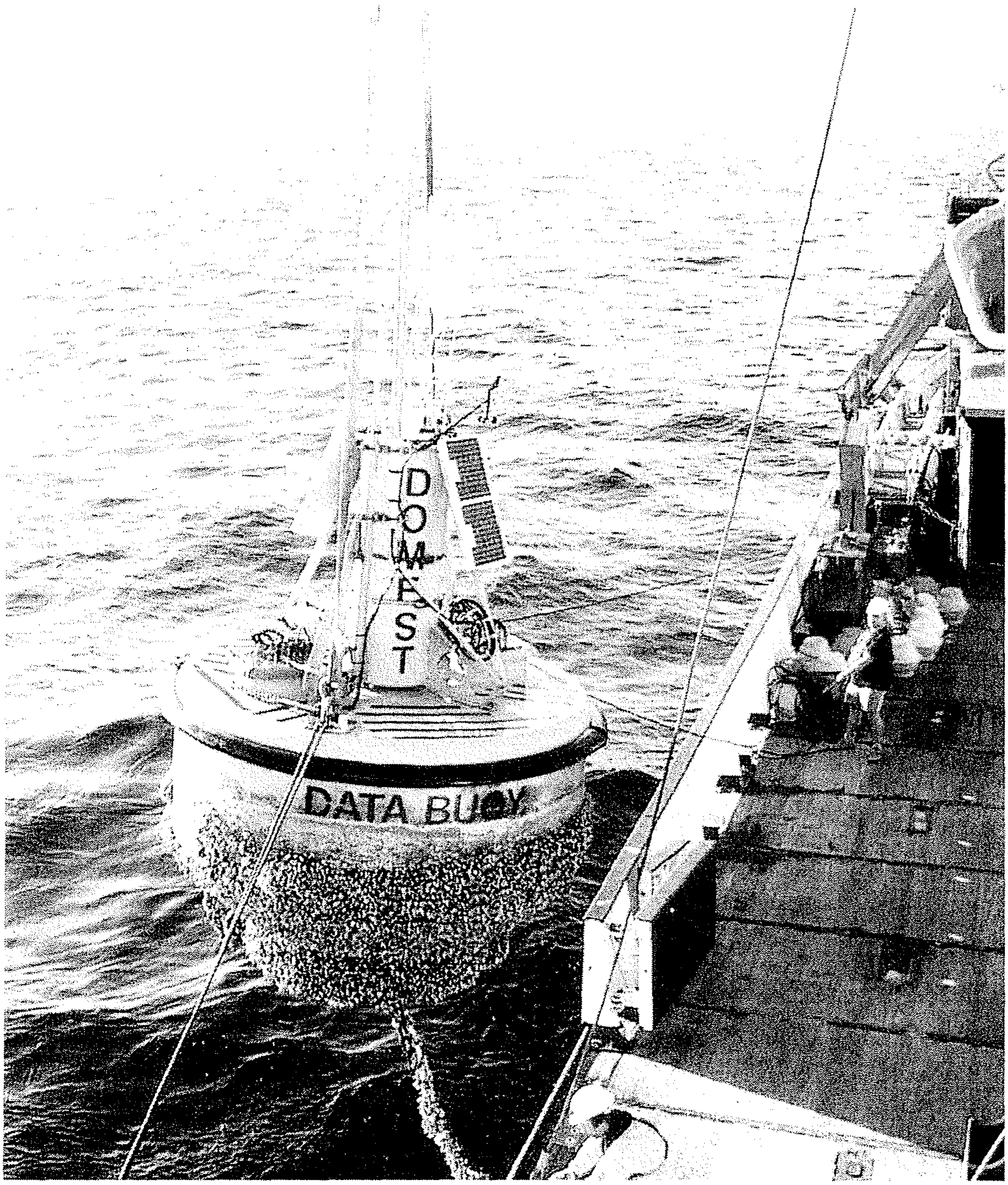

Fig. 7: DOMEST surface buoy during recovery. Visible is the intense biofouling on the subsurface parts of the buoy hull.

The electronic rack was rebuild and attached to the buoy and the electronic pocket was completely sealed. In addition a Spare OrbComm unit - complete 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.

Fig. 8: Intense biofouling at the remote transducer head and at the 25 m chain of the DOMEST surface buoy.

5.5.4 Deployment of Moored Sensor Unit (MSU)

The Deep Ocean Bottom Station was moored during the M42-4 cruise in 3600 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 conditions.

For the next steps in device testing, the frame of the platform was used as the Sub Surface Platform (SSP, comp. Figure 6) 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 near the surface buoy mooring in order to run the communication tests.

5.5.5 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 lying near both moorings, in order to monitor the underwater acoustics running between SBU, DOBS and MSU. The buoy was remote controlled via the SATEL packed radio link for the next tests. This radio link was completely comparable to the OrbComm satellite link, talking on software architecture basis. Because it is complete independent from satellite presence, it is a direct and easy to use online bi-directional test link. Now, the same test has been performed as on former tests, means requests for status data, weather data and position data of the buoy. All these data were transmitted to the Meteor via SATEL radio link. The same has been done for the underwater clients. From aboard the Meteor the buoy was programmed to asked 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 has been monitored with the deck unit and stored with the DAT tape onboard the Meteor.

5.5.6 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 has been 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 has worked well. It was no problem the get test messages and status data from the DOBS, deployed in 3500 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 3580 m water depth via the ships wire and stopped 50 m above the seafloor. Now, the second pair of acoustic releaser – mounted between DOBS and ships wire at the top of the DOBS - were released and the DOBS settled down to the seafloor and left in place till October 1999 for the M45-5 cruise.

5.6 Deep Ocean Profiler (DOP)

(Christoph Waldmann, Markus Bergenthal, Wolfgang Metzler)

During the METEOR cruise M45/1 further tests of the deep sea profiling instrument carrier DOP has been carried out. These second series of *in-situ* tests were 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 (Figure 9). 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:

- 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 hours 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 allows an easier localisation of possible failure sources.

5.6.1 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.

5.6.2 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 litres 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 litres 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 litres. Accordingly one achieves a maximum propulsion force of 1.5 kg. With 2 litres 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 modus 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 modus 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 (Figure 10, 11) 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 figure 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.

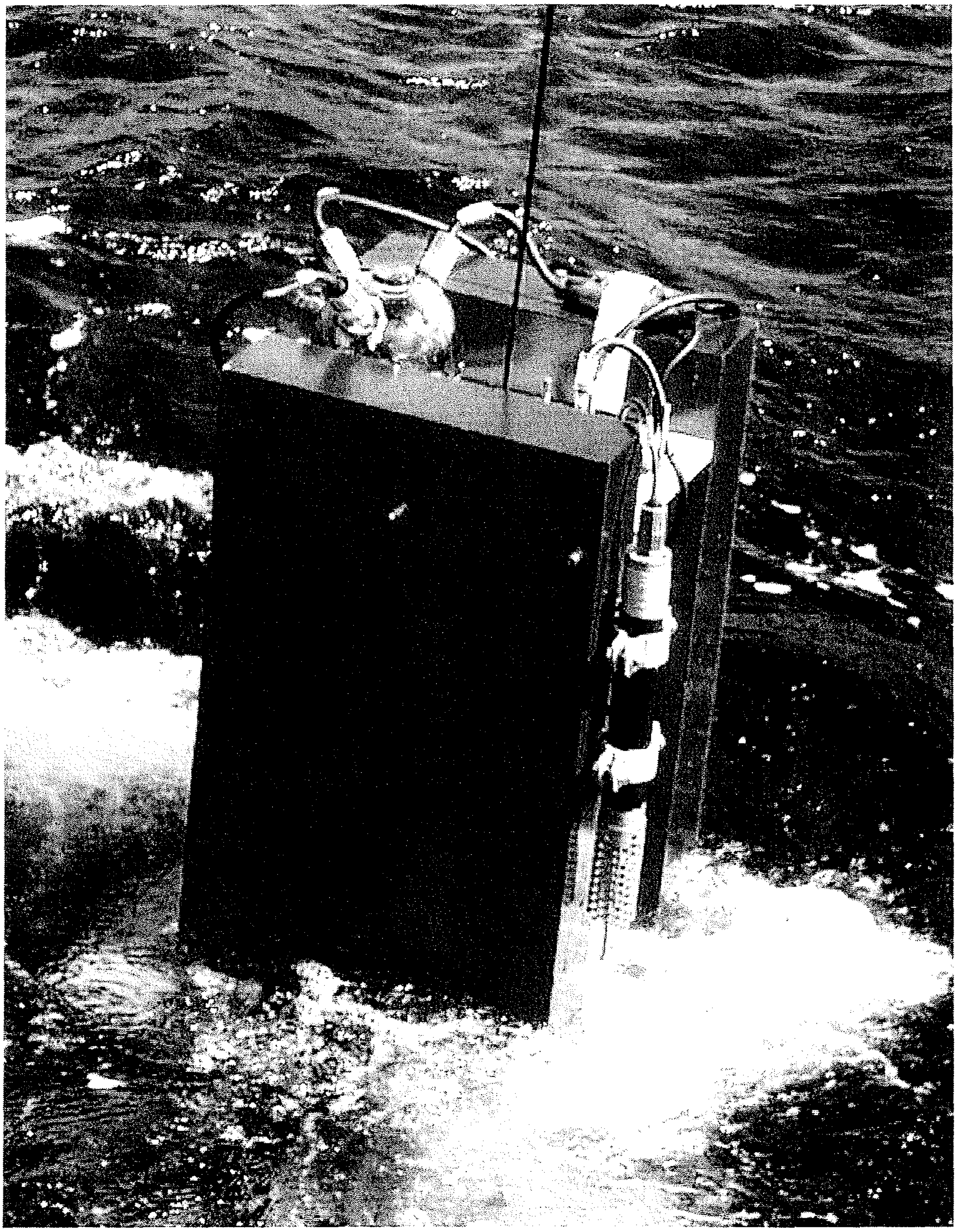

Fig. 9: The deep sea profiler DOP during deployment from RV METEOR.

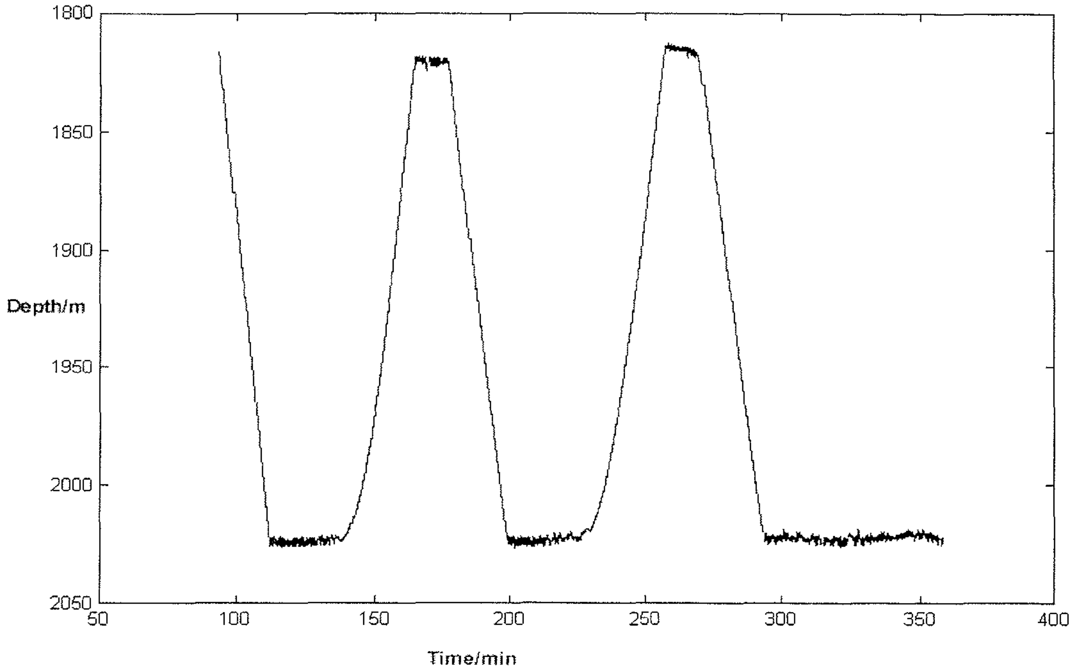

Fig. 10: Pressure measurement taken with the external pressure sensor of DOP showing the smooth motion of the profiler.

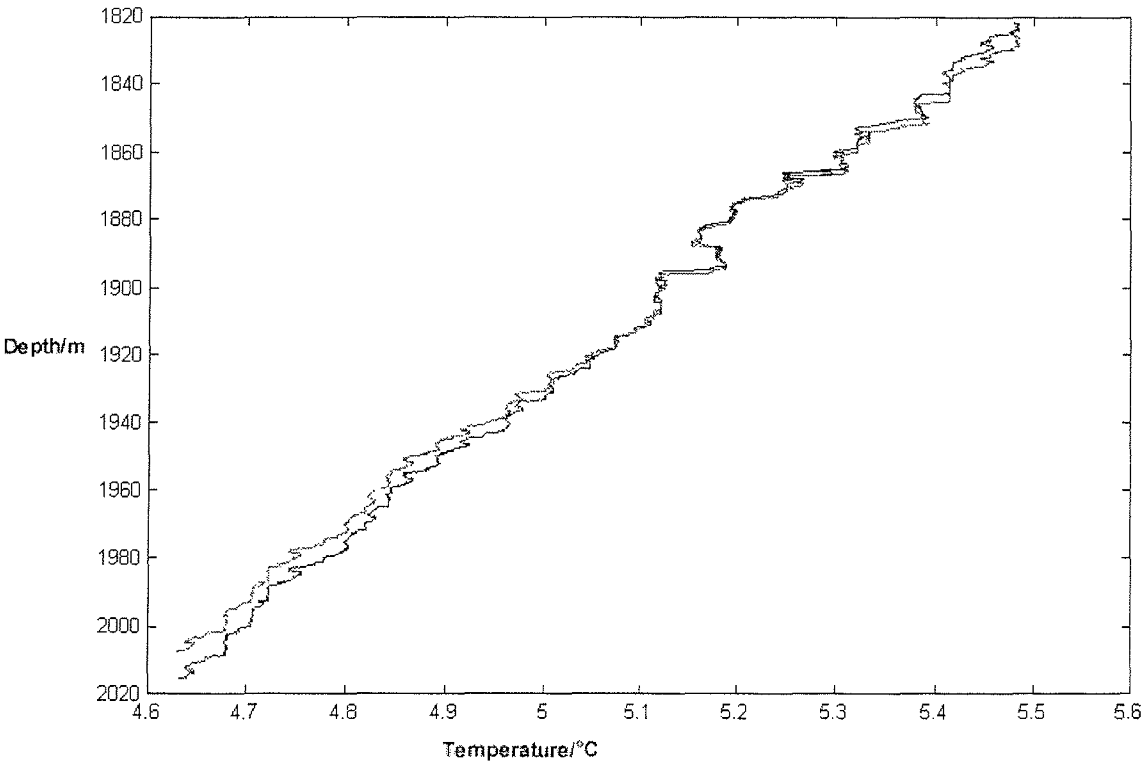

Fig. 11: Two successive temperature profiles recorded by the ME-CTD sensor showing the high reproducibility of the temperature measurement.

5.7 Field tests of the optical density sensor OPRA

(Christoph Waldmann, Markus Bergenthal, Wolfgang Metzler)

The *in-situ* going optical density sensor OPRA (Figure 12) that was developed recently at the University of Bremen (Centre for Marine Environmental Sciences, MARUM) was deployed four times during the 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 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 (Figure 13).

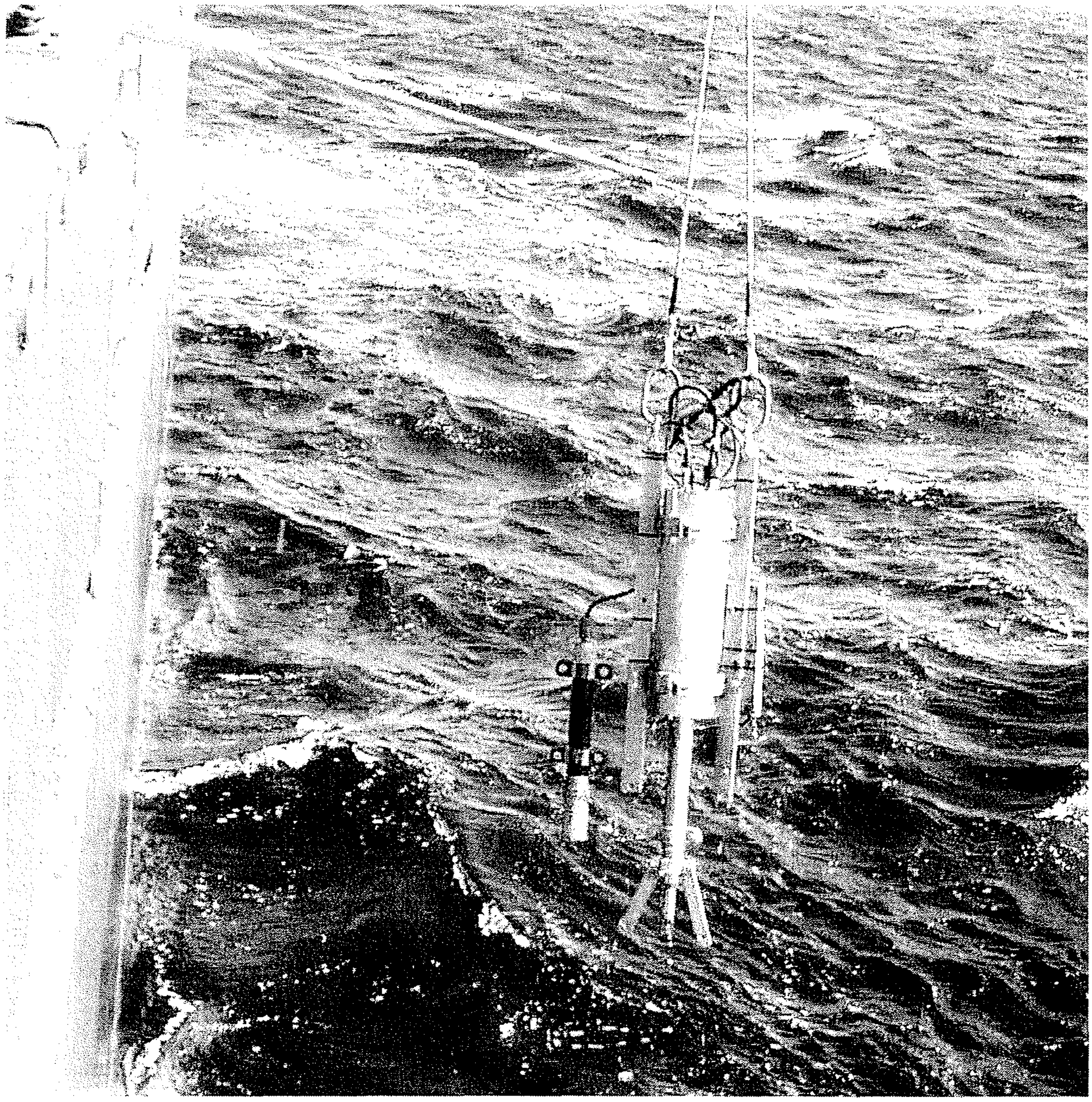

Fig. 12: The sensor OPRA together with a CTD during deployment from board RV METEOR.

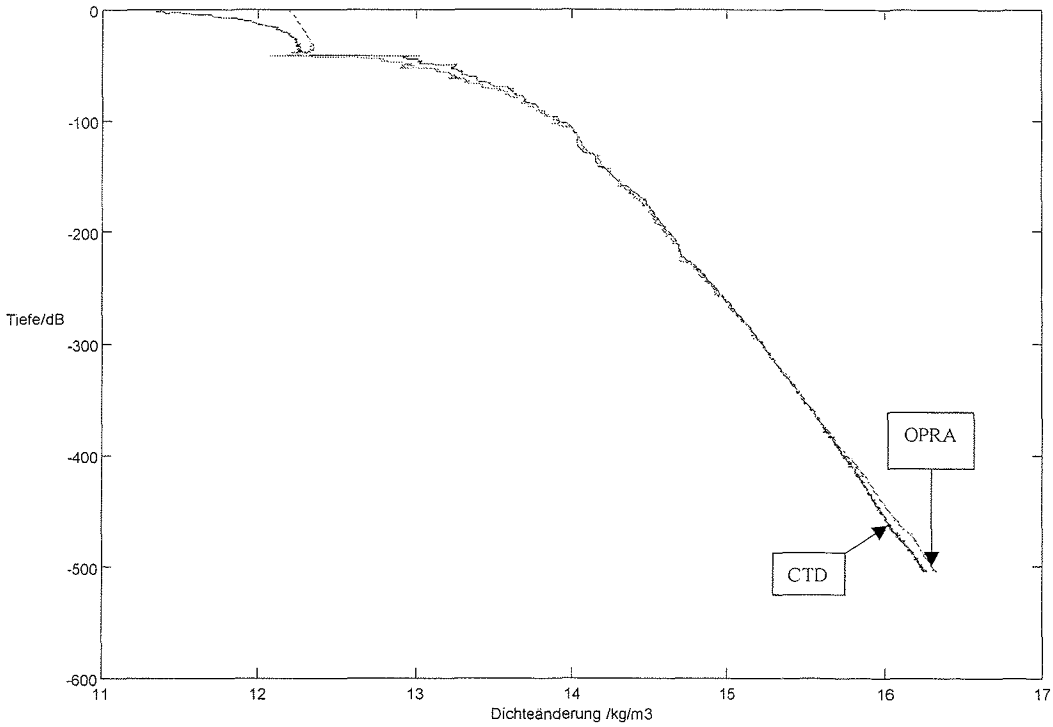

Fig. 13: Parallel *in-situ* measurement of the density with the optical sensor OPRA (Grey) and a CTD (Black).

5.8 Marine Chemistry

(Caroline v. Oppen, Aloys Deeken, Ole 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

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 μm 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.

6. SHIPS METEOROLOGICAL STATION DURING CRUISE M 45/1

(Dr. Lothar Kaufeld, W. Th. Ochsenhirt)

After having left the harbour of Malaga at May 19th at about 10.00 hours, the wind blew from southwest with increasing forces 5 to 6 bft. The well known funneling effects caused the wind to freshen up in the Strait of Gibraltar. There it reached 7 bft from westerly direction despite of only weak pressure differences between the Gulf of Cadiz and the Alboran Sea. Due to the short fetch, the wind sea was not adapted to this wind force.

The next few days with scientific measurements in the Gulf of Cadiz, a northerly breeze blew with force 4 associated with a bright sky. During the two days passage to Lanzarote northerly winds with 5 bft were observed.

From May 25th to 31st during the research work north of the Canary Islands, only weak winds occurred from northerly directions. The visibility was good to excellent: Sometimes the northeastern part of Teneriffa could be seen and once even the volcano Pico de Teide in a distance of 120 km. In the morning of May 31st, an old depression which had penetrated the subtropical ridge and had reached the region north of Madeira caused some showers in the ships vicinity.

By the change of the months, a weak depression moved northeastward away from the Portuguese coast and a strong anticyclonic ridge extended eastward from the Azores high. Since the heat depression over Northwest Africa remained stationary, the pressure differences around the Canary Islands intensified. This weather development was well forecast several days in advance by the numerical model of *Deutscher Wetterdienst.* On the cruise leg to Lissabon the northnortheasterly wind increased to 6 bft during the night to June 4th and shortly reached 7 bft.

The last four days of this cruise, RV METEOR gradually „sailed“ into the regime of the anticyclonic ridge with weakening winds from northerly directions. For a short time they freshed up a little before entering the mouth of the Tejo river.

In the morning of June 8th, this voyage ended in Lissabon with bright sunshine.

7. STATION LIST M45-1

Date	*Stat.-No.*	*Device*	*Lat. (°)*	*Lon. (°)*	*WD (m)*	*Rec.*	*Remarks*
Golf of Cadiz							
20.05.	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	
20.05.	5902-1	SL 6	36 36,67 N	007 00,88 W	494	0	Tube empty
	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	
20.05.	5903-1	CTD	36 01,42 N	007 40,02 W	1095		
	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	
20.05.	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	
21.05.	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	Core-Top disturbed
21.05.	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	
21.05.	5907-1	CTD	36 20,00 N	008 09,97 W	1487		
	5907-2	MUP	36 19,99 N	008 10,00 W	1487		2 Pumps (450 m)
	5907-3	MUP	36 20,23 N	008 10,53 W	1445		8 Pumps (700 m)
22.05.	5907-4	RO	36 20,23 N	008 10,54 W	1443		
	5907-5	MUP	36 20,68 N	008 10,64 W	1394		5 Pumps (1350 m)
	5907-6	OPRA	36 20,00 N	008 09,98 W	1487		(150 m)

Canary Islands / DOMEST Area

25.05.	5908-1	MUP	29 10,51 N	015 54,29 W	3631	2 Pumps (720 m)
	5908-2	RO	29 10,52 N	015 54,21 W	3631	(1074 m)
		SB	29 10,20 N	015 55,09 W		Recovery of Surface Buoy
		DOBS	29 10,11 N	015 56,01 W		Recovery of DOBS Mooring
25.05.	5909-1	DT_1	29 10,38 N	015 43,89 W	3624	Drifting Trap 1 „out"
	5909-2	RO	29 10,64 N	015 44,25 W	3625	(1049 m)
25.05.	5910-1	MUP	29 10,75 N	015 26,77 W	3608	8 Pumps (full depths)
26.05.	5910-2	RO	29 10,67 N	015 26,94 W	3609	(full depths)
	5910-3	DOP	29 10,66 N	015 26,79 W	3609	(50 m)
		DOP	29 10,68 N	015 26,78 W	3608	(50 m)
		CI 10	29 11,21 N	015 24,91 W		Recovery of CI 10
		CI 11	29 10,51 N	015 25,85 W		Deployment of CI 11
	5910-4	MUP	29 08,55 N	015 25,84 W	3606	8 Pumps (1500 m)
	5910-5	MSD	29 08,54 N	015 25,91 W		COM test (1000 m)
27.05.	5910-6	ParCa	29 08,61 N	015 25,94 W	3607	(full depth)
	5910-7	RO	29 09,07 N	015 25,03 W	3605	(1104 m)
	5910-8	DOP	29 09,11 N	015 24,86 W	3604	(500 m)
		DOP	29 09,19 N	015 24,71 W	3606	(800 m)
	5910-9	MSD	29 09,14 N	015 24,81 W	3605	COM test (2000 m)
	5910-10	OPRA	29 09,17 N	015 24,82 W	3605	(400 m)
	5910-11	ParCa	29 09,17 N	015 24,82 W	3604	(200 m)
	5910-12	MUP	29 09,17 N	015 24,82 W	3608	8 Pumps (220 m)
28.05.	5910-13	RO	29 09,17 N	015 25,40 W	3607	(1044 m)
	5910-14	MUP	29 09,12 N	015 25,43 W	3607	8 Pumps (200 m)
28.05.	5911-1	DT_1	29 05,46 N	015 31,41 W		Drifting Trap 1 „in"
	5911-2	DT_2	29 05,32 N	015 31,44 W		Drifting Trap 2 „out"

28.05.	5912-1	MSD	29 10,51 N	015 54,06 W	3652	COM test (2000 m)
		MSD	29 10,48 N	015 54,09 W	3645	COM test (1000 m)
	5912-2	DOP	29 10,48 N	015 54,06 W	3647	(800 m)
	5912-3	UWW	29 10,50 N	015 54,07 W		(900 m)
	5912-4	MUP	29 10,52 N	015 54,02 W	3632	8 Pumps (1100 m)
	5912-5	MUP	29 10,49 N	015 54,08 W	3632	8 Pumps (2500 m)
29.05.	5912-6	SB	29 10,43 N	015 55,19 W	3633	Re-deployment SB
	5912-7	MSD	29 10,47 N	015 54,39 W	3633	COM test (MSD-SB, MSD 2000 m)
	5912-8	UWW	29 10,47 N	015 54,42 W	3632	(200 m)
		UWW	29 10,47 N	015 54,42 W	3632	(200 m)
		UWW	29 10,48 N	015 54,39 W	3632	(200 m)
30.05.	5912-9	DOP	29 10,76 N	015 54,53 W	3633	(1500 m)
	5912-10	MUP	29 10,99 N	015 54,55 W	3631	8 Pumps (200 m)
	5913-1	MSU	29 08,78 N	015 52,49 W	3631	Short time deployment MSU mooring
30.05.	5914-1	DT_2	29 04,93 N	015 15,53 W	3592	Recovery of DT_2 mooring
	5914-2	RO	29 04,90 N	015 15,59 W	3592	(200 m)

Canary Islands / La Palma Area

31.05.	5915-1	LP-3	29 44,85 N	017 54,86 W	4322	Final recovery of LP-3 mooring
	5915-2	OPRA	29 44,49 N	017 53,62 W	4322	(1000 m)
	5915-3	MUP	29 44,83 N	017 54,22 W	4333	8 Pumps (1520 m)
01.06.	5915-4	DOP	29 44,85 N	017 54,24 W	4332	(2500 m)
	5915-5	MUP	29 45,27 N	017 54,55 W	4335	(400 m)
	5915-6	RO	29 45,32 N	017 54,54 W	4335	(1503 m)
	5915-7	MUP	29 45,77 N	017 54,82 W	4340	(980 m)

Canary Islands / DOMEST Area

02.06.	5916-1	UUW	29 10,79 N	015 56,46 W	3634	(200 m)
	5916-2	SB/DOBS	29 09,99 N	015 51,66 W		Satellite tests
		SB/MSU	29 08,67 N	015 52,37 W		SB-DOBS-MSU
	5916-3	MUP	29 09,56 N	015 51,93 W	3631	8 Pumps (3020 m)
	5916-4	ParCa	29 09,59 N	015 51,96 W	3629	(full depth)
03.06.	5916-5	DOP	29 09,60 N	015 51,93 W	3630	(2500 m)
03.06.	5917-1	MSU	29 08,27 N	015 52,15 W		Recovery MSU mooring
	5917-2	DOBS	29 10,94 N	015 55,85 W	3634	Deployment of DOBS
	5917-3	COM	29 10,43 N	015 55,86 W	3634	COM test (DOBS)

North Atlantic (Sound Source Moorings)

06.06.		IO1	35 27,98 N	010 11,42 W	4021	Recovery of Portuguese IO1 mooring failed, top buoyancy collapsed
	5918-1	DOP	35 28,06 N	010 11,28 W	4014	(2000 m)
		COM	35 28,51 N	010 11,56 W		Pos. check for IO1
07.06.		IO2	36 09,07 N	011 10,59 W	4786	Recovery of Portuguese OI2 mooring

Abbreviations:

SL6	Gravity Corer (6 m Core tube)
SL12	Gravity Corer (12 m Core tube)
CTD	Conductivity, Temperature, Density Measurement
MUC	Multi Corer
MUP	Multi- and Single Pumps for Chemical Component pumping
RO	Rosette Water sampler (12 Bottles)
OPRA	Optic Refractometer
SB	Surface Buoy (2.4 m DOMEST Buoy)
MSD	Multi Sensor Device (Sensor Suite, Sediment trap, CTD, 3D ACM)
MSU	Moored Sensor Unit (Mooring with MSD inside)
DOP	Deep Ocean Profiler /Profiling YoYo vehicle)
DOBS	Deep Ocean Bottom Station
UUW	Underwater Winch
ParCa	Particle Camera
CI	Canary Island mooring
LP	La Palma mooring
IO	Inter Ocean mooring (Portuguese Sound source mooring)
COM	Communication tests via Satellite and Acoustic Communication)

List of Device Handling during the Cruise

Device	*Tasks on M45-1*
MUC	6
SL	7
RO	8
CTD	2
MUP	15
ParCa	4
OPRA	3
DOP	9
UWW	5
MSD	4

8. REFERENCES

Asper, V. L. 1987. Measuring the flux and sinking speed of marine snow aggregates. *Deep-Sea Research*, 34: 1-17.

Honjo, S., K. W. Doherty, Y.C. Agrawal and V.L.Asper 1984. Direct optical assessment of large amorphous aggregates (marine snow) in the deep ocean. *Deep-Sea Research*, 31: 67-76.

Lampitt, R. S. 1985. Evidence for the seasonal deposition of detritus to the deep-sea floor and its subsequent resuspension. *Deep-Sea Research*, 31: 885-897.

Ratmeyer, V. and G. Wefer 1996. A high resolution camera system (ParCa) for imaging particles in the ocean: System design and results from profiles and a three-month deployment. *Journal of Marine Research*, 54: 589-603.

9. ACKNOWLEDGEMENT

The METEOR cruise M45/1 was very successful and with the exception of one Portuguese mooring IO1 all goals for instrument testing and scientific sampling tasks were achieved, much more than expected. The great success of this cruise was made possible by the exemplary performance of the entire crew. During the work on deck and in manoeuvring of the ship - especially during the complex DOMEST device handling work with the surface buoy and moored sensor unit operations - the highest competence of crew and Captain was displayed. All the time on board we have had an outstanding teamwork and a very friendly comradeship between crew and scientists. For this we very sincerely thank Captain Stefan Bülow and the entire crew of RV METEOR.