

5.6 Leg M45/5b

5.6.1 DOMEST

(G. Meinecke, V. Ratmeyer, G. Ruhland, U. Rosiak, A. Bittkau, H. Bothmer, T. Klein)

Prior to the cruise M45/5b, the first close-loop test, including data request from ship via satellite into the deep sea and back via satellite to the ship, had been successfully performed on METEOR in May 1999 (M45/1) within less than 8 minutes. The final configuration of the complete DOMEST mooring will be deployed in 3.600 m water depth over a maximum duration of one year. New sensors will provide high-resolution data on particle fluxes and element concentrations in the deep ocean.

5.6.1.1 Main Objectives for the M45/5 Cruise

The main objective for this cruise was to implement and to test the complete sensor package proposed in the DOMEST project. The complete system included 3 independent acoustic underwater clients consisting of: UW-Winch (at the SSP), the sediment trap, the camera system and the FSI-CTD/current meter (all at MSD) and the ADCP and camera system (both at DOBS), attached to an Controller PC (BC2) and to an acoustic modem. From each client scientific data may be obtained on request via an OrbComm satellite link / SATEL (Pocket radio link for short distances) and acoustic underwater communication. The FSI CTD and the sediment trap had been tested on M45/1 in May 1999. Due to the larger packet length of the ADCP data output (1.000 byte), which had to be transmitted acoustically, it was necessary to implement new software inside the controller (BC2). With this new software it was possible to transmit a JPEG-picture from the camera system acoustically in increments of 1.000 byte.

Equipment tests-One of the biggest problems facing underwater acoustic communication is possible interference with other sound sources, which may cause failure of data transmission. Therefore all acoustic tests included the ORCA Deck Unit in conjunction with an FFT-Spectrogram Software package. While the Deck Unit is transmitting a signal as an acoustic data stream into the ocean, this signal is displayed in real time on the monitor PC in the lab onboard. An experienced operator thus easily separates the transmitted signals of the different underwater clients from sources of ambient or ship's noise. Data from the DAT-Recorder and also the FFT-software may be stored either as WAV-files on hard disk or as digital sound files on DAT tapes. This monitoring system has been used with great success since the beginning of the DOMEST project.

5.6.1.2 Results of Field Tests

Maintenance of the Surface Buoy Unit (SBU): The surface buoy was serviced on M45/5 because heavy bio fouling of all components of the surface buoy had been discovered during M45/1 in May of the same year. The buoy had worked very well since that deployment, only the Spare OrbComm Satellite Unit had stopped transmitting data due to low power. After recovery of the buoy onto the deck of METEOR, the electronic pocket was opened and the electronic rack was removed to replace the electronic EPROM for a software-update. In addition, a new Spare OrbComm unit was placed at the central mast of the buoy in order to transmit tracking data on a daily base. The buoy did not show any significant bio-fouling and was deployed again after two days. While the buoy was serviced on deck, dummy glass spheres had replaced the buoy as top floats of the mooring.

Test of the underwater winch: The winch is part of the moored sensor unit (MSU) with the winch system attached to the Sub Surface Platform (SSP) in the top of the mooring. But due to bad weather conditions, the winch instead had to be attached to the ship's wire in a modem test frame. The test frame also consisted of two batteries and an acoustic client (Modem, SSP-BC2). The test frame was lowered down to 200 m water depth and the acoustic communication with the underwater winch system was tested successfully via the acoustic deck unit and transducer. The winch ran different programs (left and right turns of the cable drum), all controlled acoustically from onboard ship.

Test of the ADCP: Comparable to the test of the underwater winch system in the test frame, the ADCP was tested much in the same way. The ADCP was attached below the test frame and connected to the controller (DOBS-BC2) via a serial cable. The test frame and ADCP was lowered down to 500 water depth and the acoustic communication with the ADCP was tested via the acoustic deck unit and transducer connected to an BC2 controller. The ADCP packet length of one data stream was in the size range of 1.000 byte. Specifically for this sensor it was necessary to redesign the controlling software inside the BC2 controller. Several tests were run successfully in 500 m water depth before it was lowered to 2.000 m water depth and all tests were repeated with different transmission speeds. It was now possible to read out "real" current meter data from the ADCP and transmit the data back to the ship or buoy acoustically. The tests were performed with great success up to 1.200 baud (bit/sec). This ADCP test was one of the crucial tests of the new software, because it was planned to install the ADCP at the Deep Ocean Bottom Station in order to deploy the station for another 5 months at the seafloor.

Maintenance of the Deep Ocean Bottom Station (DOBS): The Deep Ocean Bottom Station was moored during the M45/1 cruise in 3.600 m water depth with onboard installed acoustic modem and BC2 controller. During May and June 1999 several acoustic tests had been performed successfully via satellite and acoustic links between the buoy and the DOBS. However, in September 1999 all communication tests with DOBS failed. Nevertheless, DOBS was recovered successfully and the platform itself and the electronics were in good condition. Tests of the electronics revealed battery problems.

For the next deployment of the DOBS, the platform was slightly modified and included a huge upward looking BW 150 khz ADCP. DOBS was deployed again, with attached 1 tons anchor weight on the ship's wire, and released 50 m above the seafloor with a second pair of acoustic releasers.

Acoustic field test of SBU and DOBS: With the surface buoy and DOBS on site, the next task of tests were performed with METEOR in close proximity to both moorings, in order to monitor the underwater acoustics between DOBS and SBU. The buoy was remote controlled via the packed radio link SATEL for the next tests. Because of its complete independence from satellite presence, it is a direct and easy tool to test the online bi-directional link. Communication with the buoy and the underwater clients could be performed successfully and transmitted acoustically from the seafloor to the buoy and from there via SATEL radio to METEOR. All tests were monitored with the deck unit and stored with the DAT tape onboard the METEOR.

Integration and Test of the Multi Sensor Device (MSD): The Multi Sensor Device (MSD) is the most complex device in the DOMEST project. The MSD consist of 3 scientific sensors, all with their own microcontroller inside, the FSI-CTD, the camera and the sediment trap. (Fig. 13). The FSI-CTD is a combination of CTD, acoustic current meter and backscatter sensor. The camera system is a combination of a digital video and an Image Analysis PC. Finally, the sediment trap is controlled by a small PHYTEC

micro-controller. These sensor packages were connected via their serial RS 232 interface to the BC2 controller. Inside the sensor different processes such as "wake up, boot, gather data, build up communication, send data, acknowledge ..." require different processing time and need to be fine-tuned to ensure data transmission. Part of the developmental stage of DOMEST is the identification of potential failure sources and fine tuning on each field test. On this cruise, the complete MSD could be tested. After various days of problem solving, all sensors could transmit data acoustically. The camera system could be run remotely with complete control (start, take picture, store, rewind etc.) and JPG images could be transmitted acoustically in several increments (each 1.000 byte). The communication was tested successfully with the MSD on the wire down to 1000 m water depth.

Final field test of the acoustic satellite link: With the surface buoy and DOBS deployed on site, final tests were performed. The former tests had been performed with a BC2 controller attached to the deck unit from the ship. While METEOR was leaving the DOMEST working area, we ran several data requests successfully via the mobile OrbComm transceiver onboard METEOR and test messages and status data could be obtained from the DOBS. The communication ran from METEOR via the OrbComm satellite to Italy, via satellite back to the SBU, acoustically through the water column to the DOBS which read out the data, sent these data acoustically back to the buoy which in turn transmitted via satellite to Italy and finally back to METEOR. For the first time data could be received via this coupled acoustic-satellite data link from a deep sea moored instrument.

Results and Conclusion: The work with complex electronic equipment, especially onboard a ship is prone to potential failures due to water, pressure, wave energy and ground loops. During this cruise some of these problems were encountered. But due to growing experience with each field trip combined with the complex test scenarios within DOMEST, the problems could be fixed during this cruise. The perfect support from all branches onboard METEOR was very helpful and at the end, nearly all proposed tests could be performed successfully.

5.6.2 Deep Water Tests of the Profiling Instrument Carrier DOP

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

The profiler DOP as part of the BMBF funded project DOMEST is designed to operate in an unattended manner over time intervals of up to one year. It will allow taking time series measurements of physical parameters in depths down to 4000 m. During this METEOR cruise the system was deployed five times in different depths. The results of these tests will allow a close evaluation of the operating characteristics of the system i.e. the reproducibility of the buoyancy change or the weight adjustment of the overall system. These parameters are important to reach the expected design goal.

The two basic building blocks of the profiler are the hydraulic unit encapsulated in a ceramic pressure housing and the electronic unit encapsulated in a glass housing. These rather unusual materials were chosen to reduce the overall weight of the profiler. The drawback is the relative delicate handling of the units. The propulsion of the profiler results from buoyancy change, similar to floats, by pumping oil in or out of the hydraulic unit. The maximum amount of pumped oil is 3 l.

The main goal of the tests was to prove the liability of the chosen profiler principle under field conditions. The test schedule was determined by the weight balancing procedure of the profiler. Due to the

density change in the water column it was necessary to adjust the weight of the system for different deployment depths (200m, 400m, 1600m, 2500m and 3400 m) to an accuracy of 200 g (the weight change for a depth change of 1000 m is about 500 g).

Within the final test the system was deployed at a maximum depth of 3400 m and was allowed to cycle in a 500 m water depth. The time for a full cycle is 2.5 h consisting of the pumping process of 1 h and the up and down movement of each 45 min, resulting in the final profiling speed of 17 cm/s for both directions for a pumped volume of 2 l. The energy needed for a full deep sea cycle was about 100 Wh. This energy can be lowered by several measures including a special pressure compensation method for the hydraulic unit and lowering the amount of pumped oil while keeping the speed constant by streamlining the shape.

Together with a lithium battery pack that will be used for the final tests it will be possible to achieve 100 profiles with the system within one year.

The deep sea profiler as it exists presently has proven its functionality under field conditions. Within the remaining time frame of the project DOMEST the goal will be to prove the reliability within the long-term operation of the system.

5.6.3 Field Tests of the Optical Density Sensor OPRA

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

The in situ optical density sensor OPRA was developed recently at the University of Bremen, Marum, and was deployed two times during this cruise. The deployment depth was 500 m for both tests. 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 ship 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 the refractive index with an accuracy of the order of 10^{-4} .

Interest in this sensor is manifold. It ranges from the area of physical oceanography to geological investigations dealing with salinity anomalies within the vicinity of cold sweeps. It is therefore important to further prove the liability of the sensor under in situ conditions.

5.6.4 Particle Flux Measurements with Moored Particle Traps

(G. Ruhland, V. Ratmeyer, S. Neuer, U. Schüssler, B. Lenz)

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. In addition, this long-term particle flux record indicates that a large portion of deep particle flux originates laterally (NEUER ET AL., 1997). In CANIGO, additional sediment traps were

placed along the 29°N transect, north of La Palma (mooring LP, discontinued in spring of 1999) and between the eastern Canary islands and the Moroccan shelf (mooring EBC). Including the ESTOC position, these three main trap locations covered the productivity gradient from shelf region to the oligotrophic gyre.

Mooring V377-4 (internal name EBC3-4) had been launched east of Lanzarote in the Eastern Boundary Current (EBC) during Poseidon 247 cruise in February 1999. This IfM Kiel mooring was equipped with 5 Aanderra current meters (RCM5) from Kiel and two sediment traps from Geo Bremen (Table 14). It was the 4th deployment period since January 1997, when EBC3 was implemented as part of a mooring array in the EBC within the CANIGO project. While the other moorings were deployed only 3 times during the field phase of CANIGO, EBC3 was deployed again to continue measurements of particle fluxes close to the shelf.

Mooring EBC 3-4 was recovered on 28 October. Upon recovery it became apparent that the 500 m

Tab. 14: Instruments and deployment data of deployed and recovered moorings.

Mooring	Position	Water depth	Instrument	Deployment depth	Time period
Recovered moorings					
EBC 3-4			S/MT 234	480 m	--
			S/MT 234	700 m	3.2.99 - 25.10.99
CI-11	29°10,7'N 015°25,8'W	3608m	S/MT 234	828 m	27.5.99 - 12.12.99
			S/MT 234	1117 m	--
			S/MT 234	3083 m	--
			RCM 8	853 m	27.5.99 - 2.11.99
			RCM 8	1142 m	27.5.99 - 2.11.99
			WTS 6-25-142-FF	3314 m	27.5.99 - 2.11.99
			WTS 6-25-47-FH	3545 m	27.5.99 - 2.11.99
EBC 3-5	28°44,09'N 013°18,44'W	1200 m	S/MT 230	469 m	29.10.99 - 16.05.00
			S/MT 230	664 m	29.10.99 - 16.05.00 (10d sampling interval)

S/MT 230 = Particle trap S/MT 230
 S/MT 234 = Particle trap S/MT 234
 RCM 8 = Aanderaa Current meter RCM 8
 WTS 6-25-142-FF = McLane *in situ*-Pump
 WTS 6-25-47-FH = McLane *in situ*-Pump
 WTS 6-25-47-EC = McLane *in situ*-Pump

trap had not turned during the deployment, however the 700 m trap had functioned properly. Mooring EBC 3-5 was re-deployed on the same day as a GeoB mooring with two traps in 469 m and 664 m depth, respectively.

ESTOC sediment trap mooring CI11 was recovered on 2 November. This mooring which had been deployed on M45/1 consisted of three sediment traps (S/MT 234), two current meters (RCM 8) and three *in situ*-particle pumps closely above the sea-floor (Table 14). The upper trap (828 m water depth) had functioned properly and yielded 15 samples according to the sample programming. The lower traps did not turn because of a failure of the storage unit and internal clock, respectively. The two current meters functioned properly. The *in situ* pumps yielded the full set of samples for suspended particulate matter, either contained on Polycarbonate filters or on extraction columns. The mooring was deployed again at the same location on the subsequent cruise as CI-12.

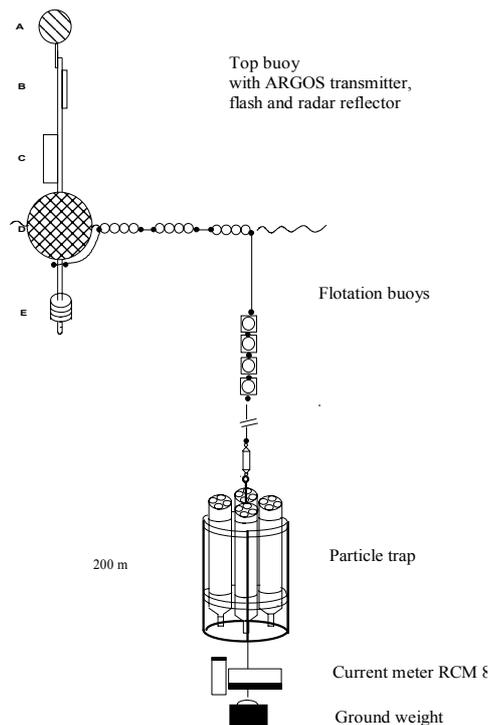


Fig. 73: Drifter I-1 carrying one trap at 200m depth.

Tab. 15: Deployment data, distance drifted and drift speed of the surface-tethered traps. I-1 to III-2 were deployed in the DOMEST area, I-3 and III-3 were deployed in the filament area.

Drifter	Deployment period	Deployment Position N, W	Recovery Position N, W	Time Deployed, h	Distance, km	Speed, cm/s
I-1	23.10-26.10	29°10.7' 015°55.7'	28°59.6' 016°0.23'	64.5	21.8	9.3
I-2	26.10-27.10	29°10.2' 015°56.9'	29°03.9' 015°57.8'	34	11.6	9.5
III-1	23.10-26.10	29°11.0' 015°55.9'	29°02.3' 016°0.4'	65	17.7	7.6
III-2	26.10-27.10	29°10.2' 015°56.7'	29°05.2' 015°57.9'	36	9.5	7.3
I-3	29.10-30.10	31°11.3' 010°27.6'	31°15.8' 010°28.1'	22.75	8.4	10.23
III-3	29.10-30.10	31°0.2' 010°45.0'	31°05.3' 010°43.6'	26	9.7	10.37

5.6.5 Experiments with Drifting Particle Traps

In addition to moored sediment traps, drifting trap experiments were carried out to determine particulate carbon flux that originated directly from the euphotic zone, both in the DOMEST/ESTOC as well as in the Cape Ghir filament area (Table 15). Ideally, these sinking flux measurements need to be coupled with measurements of the standing stock and production rates of the plankton community in the euphotic zone (see 5.6.1.1). These experiments were designed in parallel to experiments carried out on POSEIDON in February of the same year (NEUER ET AL., 1999).

Two surface-tethered particle interceptor arrays were deployed, one carrying one trap at 200 m (Trap I, Fig. 73), the other one with two additional traps at 300 and 500m depth (Trap III). 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.

In total two parallel deployments were made in the DOMEST area and two in the filament area. In general, the array carrying three traps drifted slower than the short array; drifting speeds were generally faster in the filament area than in the DOMEST area (Table 15).

The trap samples were fixed with 2% formalin and, before analysis on shore, swimmers (zooplankton that had entered the traps actively) will be removed and the particulate material analysed for dry weight, particulate organic carbon and nitrogen content.

5.6.6 Physical Oceanography

(B. Lenz, L. Böhme, A. Cianca)

a) Methods

CTD Measurements: Measurements with a Conductivity-Temperature-Depth (CTD) recording FSI were carried out near the ESTOC and DOMEST positions, between Lanzarote and Africa (Eastern Boundary Current), in the Cape Ghir area and during a section between Cape Ghir and ESTOC (Fig. 74a, b). The FSI-CTD was operated together with a General Oceanics rosette carrying 21x10 l or 22x10 l Niskin bottles.

The FSI-CTD has a laboratory calibration for the temperature and pressure sensors according to the standards of the World Ocean Circulation Experiment (WOCE). A Beckman oxygen sensor recorded oxygen current and the temperature inside of the sensor. Salinity samples from the Niskin bottles were taken to check the correct closing of bottles, and samples from the deep ocean in low gradient zones were taken to calibrate in-situ conductivity and salinity of the CTD.

Salinity measurements with a Guildline AUTOSAL 8400 A were carried out after the cruise in a temperature-regulated laboratory at the ICCM. After processing, calibration and averaging to 2 dbar intervals, the accuracy of the FSI-CTD data are expected to be better than 1 ppt for pressure (e.g. 6 dbar for a pressure of 6000dbars), better 0.002 mK and better 0.003 in salinity.

For almost every station one of two available Seabird 19 CTDs from GeoB was attached to the rosette. Both SB CTDs are equipped with Beckman oxygen sensors. SB Sn.613 carried a transmissometer, SB Sn.2069 a fluorometer. Both CTDs have laboratory calibrations performed by the manufacturer.

Continuously registered data: With a cycle of 10 seconds the ship's position determined with the GPS navigational system, meteorological data, data from the ship thermosalinograph and from the echosounders were recorded. In total nearly 80 parameters are available.

Control and corrections of temperature and conductivity/salinity of the thermosalinograph were obtained by comparison with CTD data, salinity samples from surface Niskin bottles and samples from the thermosalinograph itself. The accuracy of temperature is expected to be better than 5mK and the accuracy of salinity is better than 0.008.

XBT: Measurements were made using Shipican T7 (Deep Blue) probes, capable of measuring down to 760 m for ship speeds up to 20 knots. Following WALSH (1996) data in the upper 5 m are removed from the files because of the finite response time of the probe (0.63 s), generating unrealistic temperature values during the transition from air to water temperatures. A rate of fall of 6.5 m s⁻¹ corresponds to a depth of 4.08 m. The deployments were made under way from Gran Canaria to ESTOC, with a nominal spacing between samples of 10 nautical miles (in total, 6 launches).

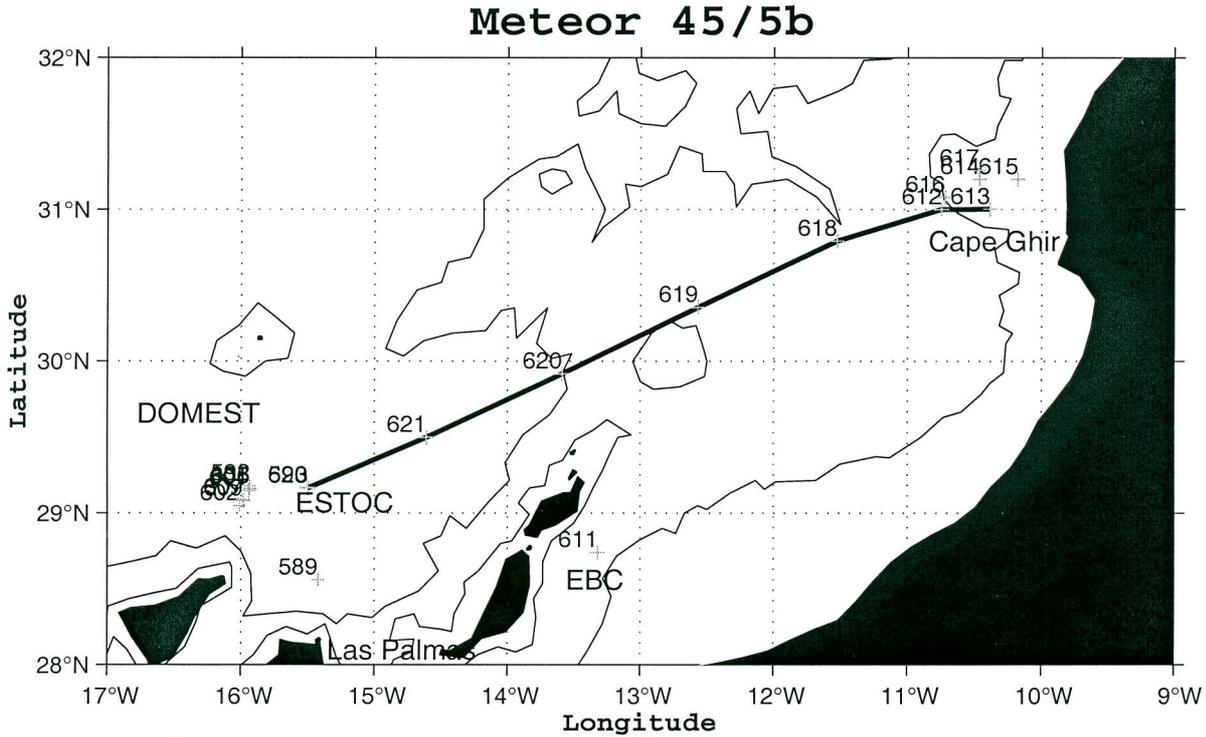


Fig. 74a: Positions of CTD Stations. The bold line indicates the location of the Transect ESTOC - Cape Ghir shown in the following Figures.

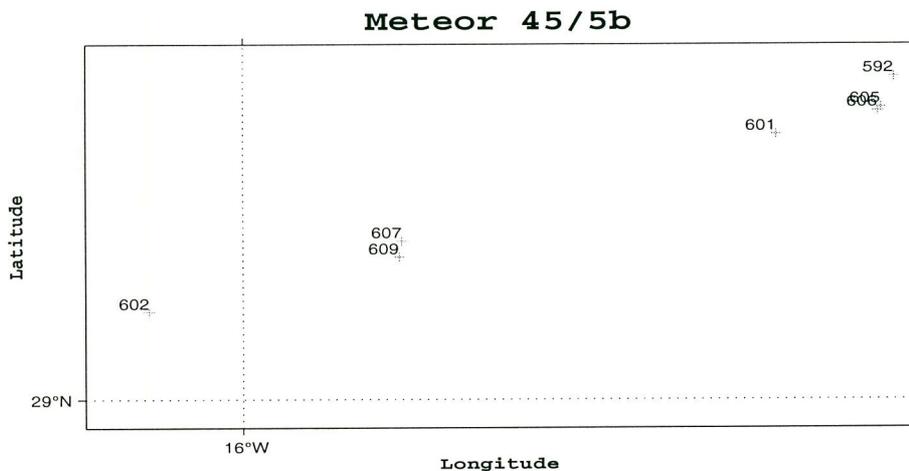


Fig.74b: Positions of CTD Stations near DOMEST.

b) First results

CTD: In the ESTOC/DOMEST area 12 profiles were recorded, 9 at the beginning of the cruise and 3 at the end, including the monthly sampling at ESTOC for October and November. One profile was recorded after recovering mooring V377-4 near the mooring site to calibrate the temperature sensors of the Aanderaa current meters (station 611). 6 profiles were obtained in the Cape Ghir area and another 5 profiles while steaming from Cape Ghir back to the ESTOC/DOMEST area. Fig. 74a, b shows the positions of all CTD casts, Table 16 lists all positions, CTD depths and informations about the SB19 CTDs.

Temperature and salinity show maximums at the surface between 14° 45' W and 13° W (Fig. 75 and 76). This situation differs from earlier observations in February this year (Poseidon 248), where we found a constant decrease in temperature and in salinity towards the coast. The temperature difference between

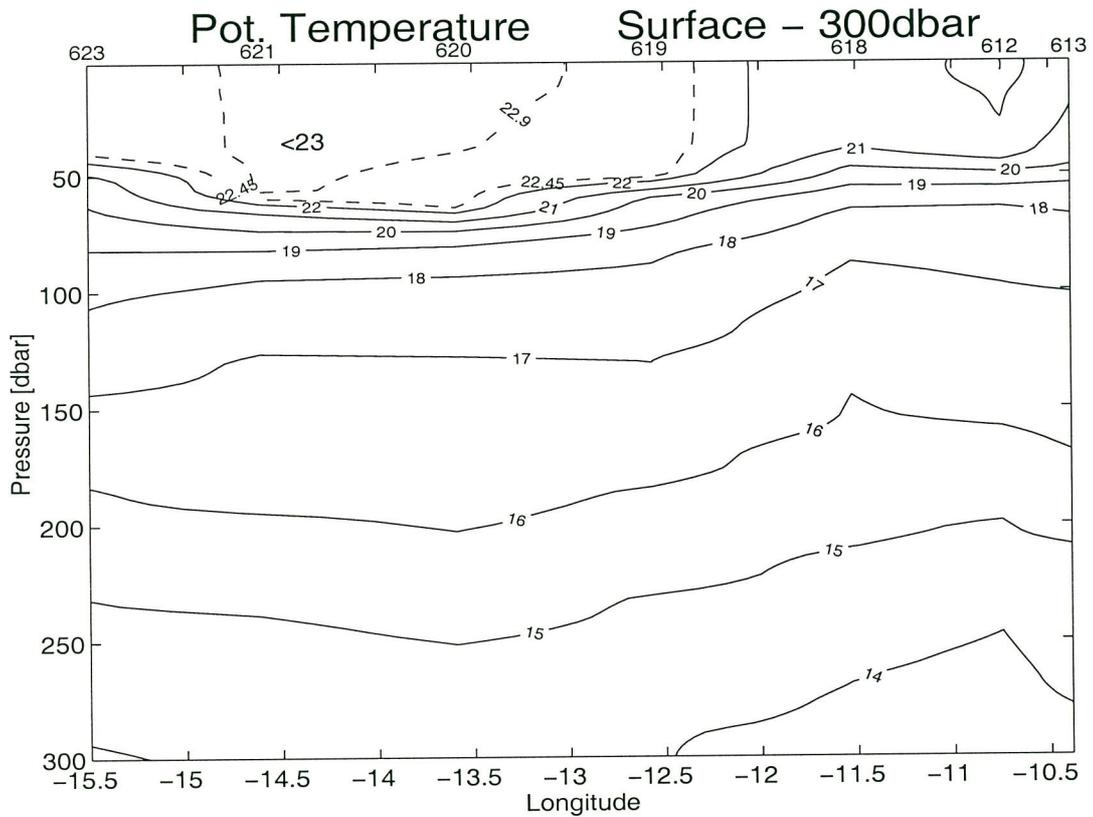
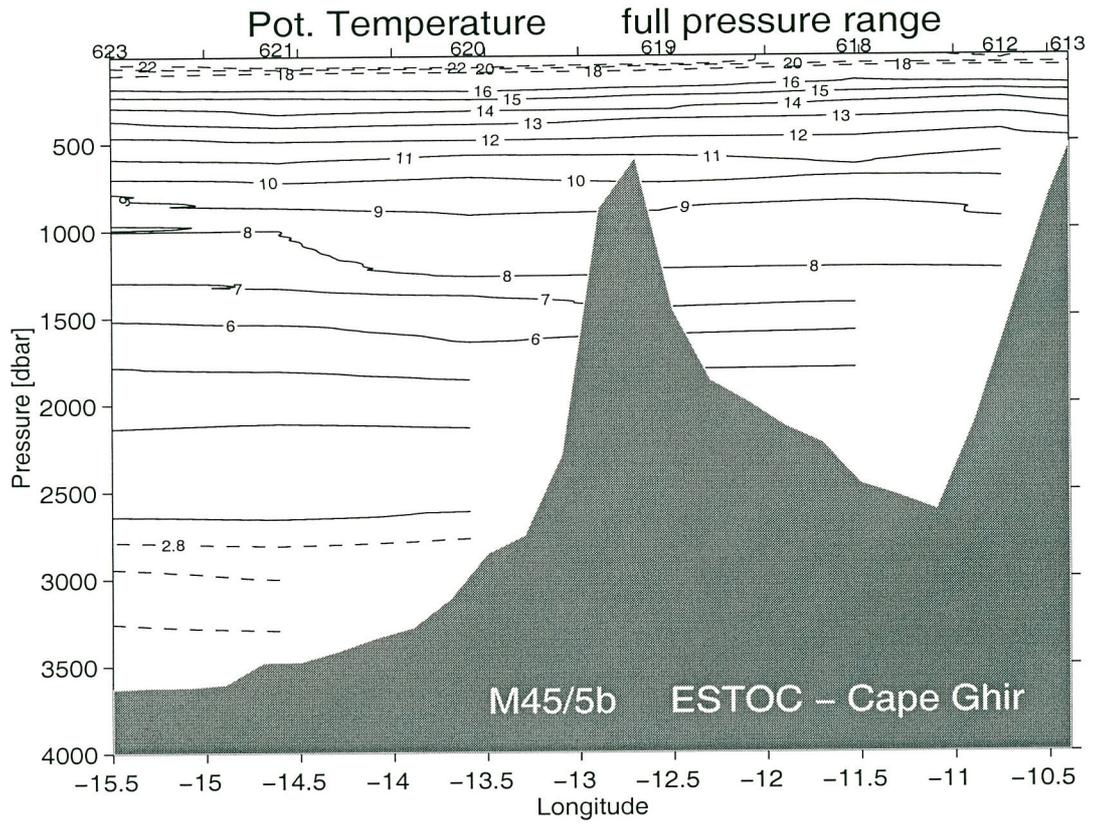


Fig. 75: Potential Temperature sections between ESTOC position and Cape Ghir area. Upper figure: full pressure range, lower figure: upper 300 dbar.

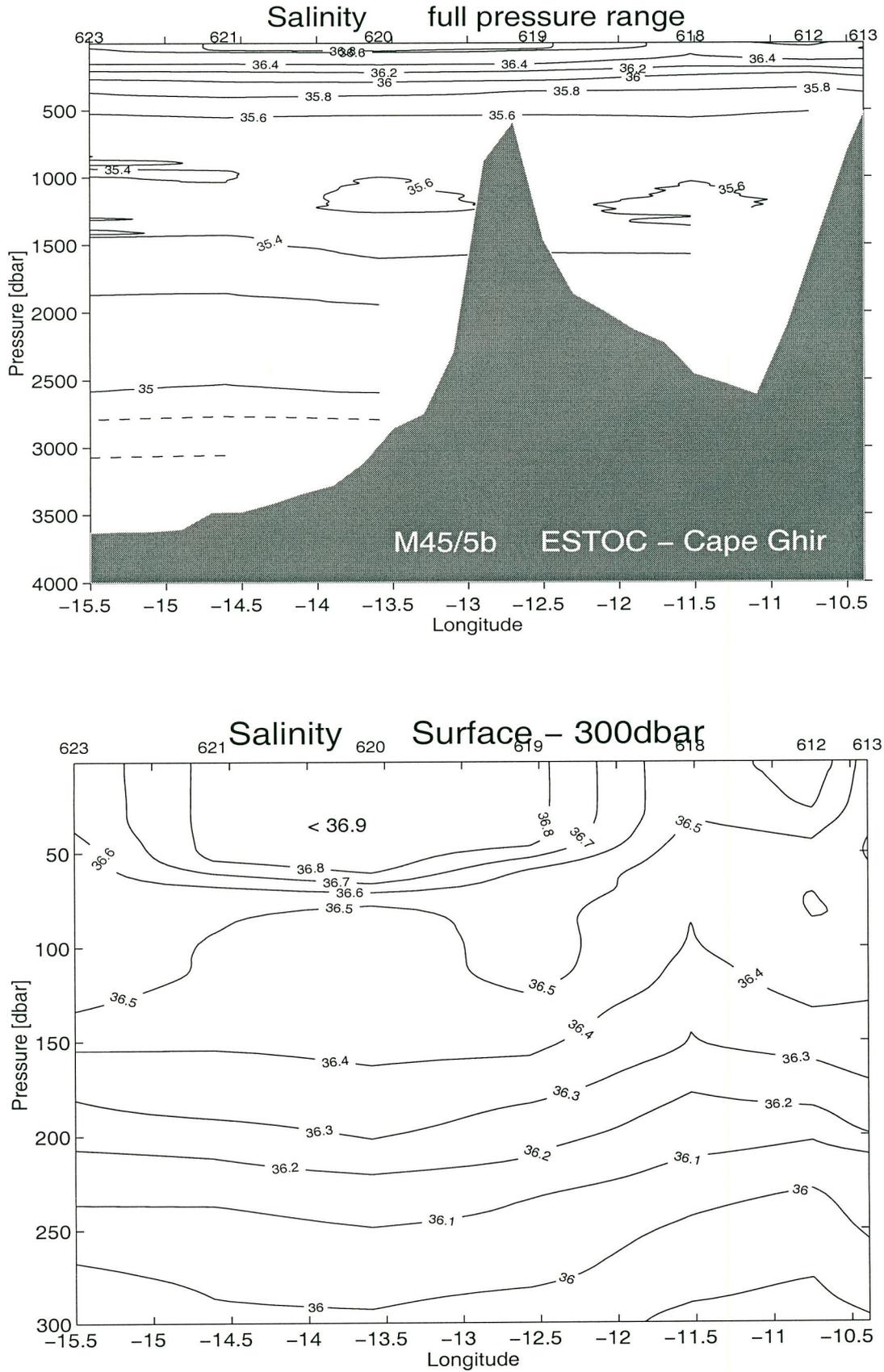


Fig.76: Salinity sections between ESTOC position and Cape Ghir area. Upper figure: full pressure range, lower figure: upper 300 dbar.

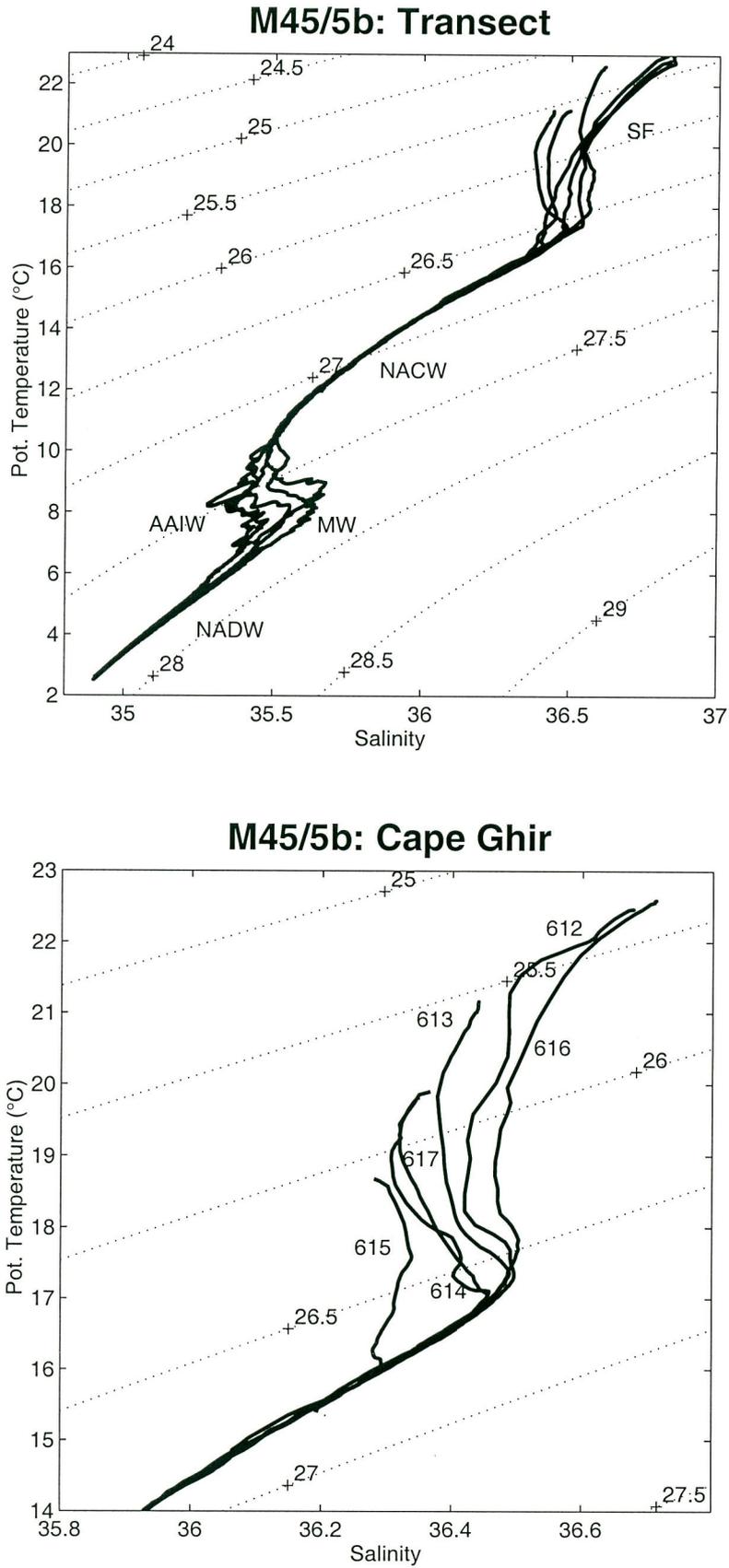


Fig. 77: θ/S relations of selected casts: upper figure: θ/S along the transect, lower figure: θ/S in the Cape Ghir area.

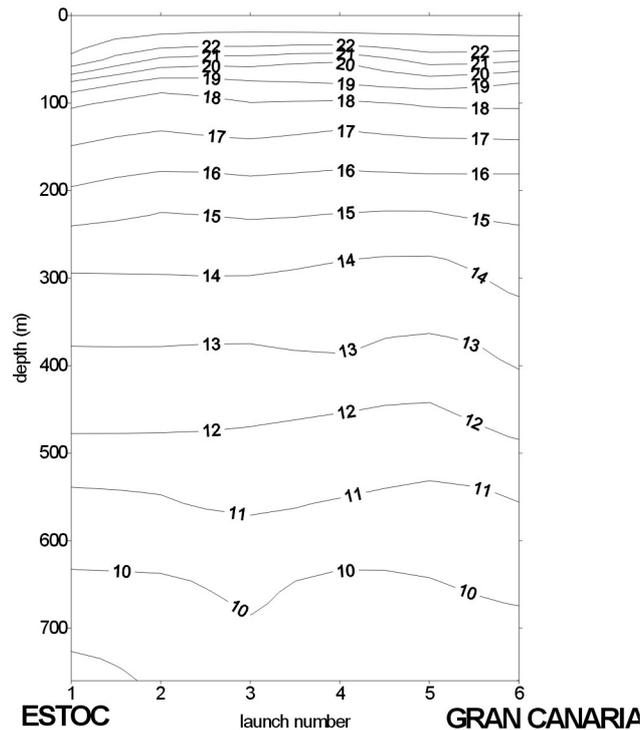


Fig. 78: Temperature distribution obtained from six XBTs launched between Gran Canaria and the ESTOC station.

Tab. 16: FSI- & Seabird CTD stations during M45/5b.-9: no Seabird attached to rosette; 613: Seabird 613 with transmissometer attached; 2069: Seabird 2069 with fluorometer attached.

Stat	Cast	Date YYYY MM DD	Hour	Latitude N	Longitude E	Depth m	Pmax dbar	CTD Seabird	Comments
589	1	1999 10 22	12.250	28.5574	-15.4231	3550	1004	-9	
590	2	1999 10 22	19.883	29.1698	-15.4999	3613	3662	-9	Estoc Oct.
593	3	1999 10 23	13.383	29.1820	-15.9303	3632	504	-9	
601	4	1999 10 25	11.350	29.1494	-15.9428	3632	500	2069	
603	5	1999 10 26	5.000	29.0492	-16.0100	3624	500	-9	OPRA att.
605	6	1999 10 26	10.500	29.1647	-15.9317	3630	496	2069	
606	7	1999 10 26	17.650	29.1626	-15.9320	3630	200	2069	
607	8	1999 10 27	4.817	29.0891	-15.9830	3618	202	2069	
609	9	1999 10 27	17.333	29.0800	-15.9833	3618	498	2069	
611	10	1999 10 28	15.367	28.7416	-13.3175	1274	1270	2069	
612	11	1999 10 29	14.200	31.0020	-10.7493	1247	1240	2069	
613	12	1999 10 29	18.550	31.0004	-10.3882	494	482	2069	*
614	13	1999 10 30	5.000	31.1988	-10.4633	512	498	-9	
615	14	1999 10 30	8.650	31.1987	-10.1782	175	170	-9	
616	15	1999 10 30	13.617	31.0806	-10.7241	995	498	2069	
617	16	1999 10 30	17.783	31.2568	-10.4704	517	200	2069	
618	17	1999 10 31	1.417	30.7908	-11.5265	2900	2872	613	
619	18	1999 10 31	8.917	30.3526	-12.5679	1796	1814	613	
620	19	1999 10 31	18.000	29.9168	-13.5903	2958	2988	613	
621	20	1999 11 1	5.333	29.5008	-14.6104	3477	3522	613	**
623	21	1999 11 2	2.083	29.1665	-15.4997	3614	3664	613	ESTOC Nov.
623	22	1999 11 2	6.200	29.1669	-15.5004	3615	198	2069	*
623	23	1999 11 2	7.117	29.1664	-15.4991	3615	198	-9	ESTOC Nov.

* Fluorometer data bad

** Seabird data lost due to a storage error

the winter situation (P248) and fall (M45/5b) amounts to 5K. At the ESTOC position we found low salinity values in a depth of 1000dbar which indicates a stronger influence of Antarctic Intermediate Water (AAIW) compared to earlier cruises.

Fig. 77 (upper) shows the θ/S -relations belonging to the profiles on the transect. As in earlier cruises we interpret the differences in temperature and salinity in the surface water (SF) as those of coastal upwelling effects. The North Atlantic Central Water (NACW) exhibited a uniform distribution on the entire transect. The same was true for the North Atlantic Deep Water (NADW). Between these water masses within a temperature range from 10°C down to 6°C (800dbar - 1500dbar) we found the locally variable influences of Mediterranean Water (MW) with higher salinity and temperature and the fresher and colder AAIW.

Fig. 77 (below) presents θ/S -relations for the Cape Ghir area. The diagram indicates the wide range in θ (differences of 4K) and S (differences of 0.4) in the surface water near the coast depending on the location, whether the profiles were recorded in a filament (e.g. #615) or outside (#612, #616).

XBT: The thermal distribution obtained from the XBT sampling is presented in Fig. 78. It shows a strong gradient in the upper 100 m corresponding to the seasonal thermocline, according to the available literature in the area. From 100 m to the deepest launch depth, a typical thermocline was encountered.

5.6.7 Sea-Bird Transmissiometer

(T. Freudenthal, B. Lenz, M. Bergenthal)

Along a transect from the Cape Ghir filament area to the ESTOC, the Kiel-rosette was deployed with a transmissiometer attached to a SeaBird CTD. Transmission is determined by the concentration of particulate matter in the water column. Therefore high resolution transmission profiles may supplement the studies of particle fluxes and of suspended particulate matter.

Fig. 79 shows the transmission profiles and SeaBird derived salinity. In all profiles the upper mixed layer with constant salinity was characterised by lowest transmission, i.e. highest concentrations of particulate matter. Comparison of euphotic zone transmission of the different stations showed lowest transmission at filament site STA 618. Below the euphotic zone transmission values were generally higher. In three (STA 618, 621, 623) of the four profiles a local minimum of transmission was observed at about 1000 m water depth just above the salinity maximum at 1150 m water depth, indicating the presence of MOW. This transmission minimum was most pronounced at filament site St. 618. A strong density gradient above the core of MOW may hinder particles from settling in greater water depth and thus be responsible for higher concentrations of particles at about 1000 m water depth. Approximately 100 to 300 m above the sea-floor transmission decreased again indicating resuspension and the presence of a bottom water nepheloid-layer.

5.6.8 Chemical Oceanography

(A. Cianca, J. Godoy, L. Maroto, M.-J. Rueda, M. Villagarcía)

a) Sampling and methods

During M45/5b water samples were taken from 10 l Niskin bottles of the CTD/rosette to analyse oxygen, nutrients, Gelbstoff and chlorophyll "a", both at ESTOC and along the transect from Cape Ghir to ESTOC. Samples were collected immediately after the bottles were on board from each depth. All samples were

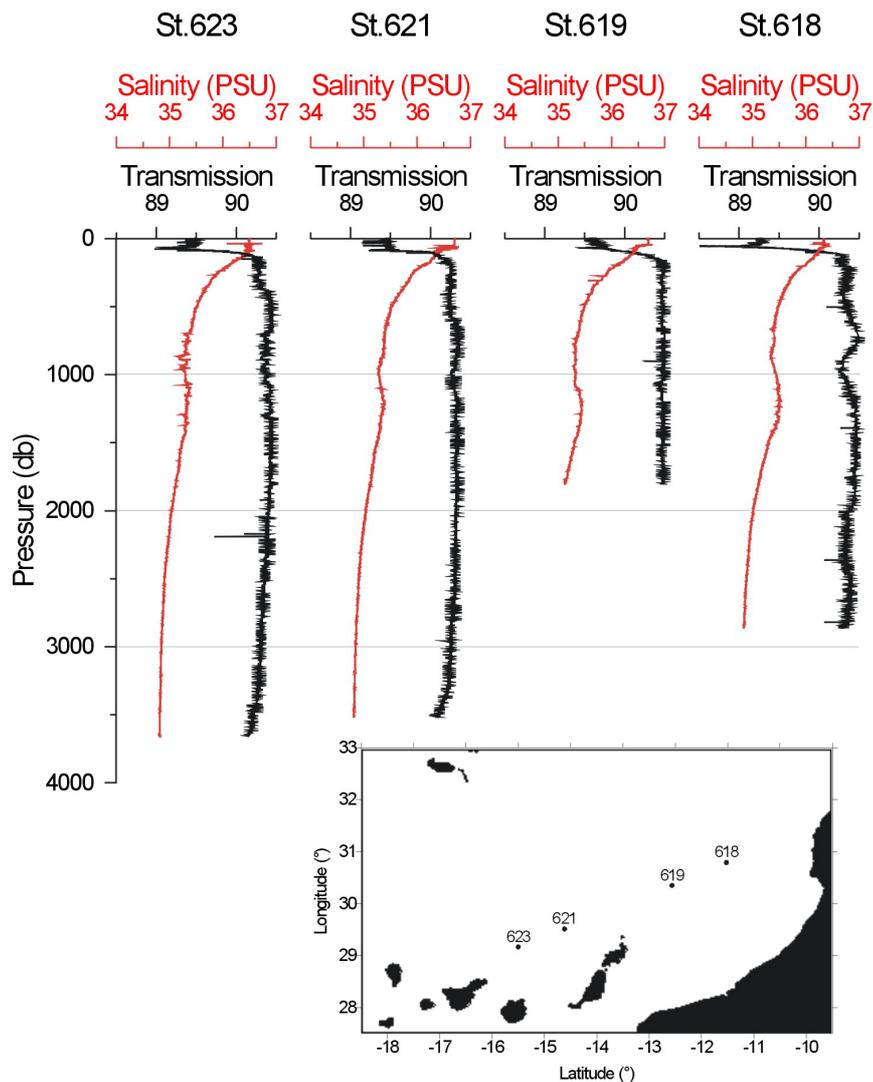


Fig. 79: Transmission and SeaBird derived salinity along a transect from the Cape Ghir filament area (St.618) to ESTOC (St.623).

taken and parameters analysed according to the procedures established in the World Ocean Circulation Experiment (WOCE, 1994). In addition, Gelbstoff fluorescence spectra were measured with a Shimadzu Model RF-1501 Spectrofluorometer. Spectral calibration of the instrument was carried out as described in DETERMAN ET AL. (1994). Fluorescence intensities were standardized to the integrated water Raman scatter band for the given excitation wavelength and denoted as Raman units DETERMAN ET AL. (1996). Chlorophyll a was determined on board by fluorometry, following the methodology described by WELSCHMEYER (1994) using a TURNER 10-AU fluorometer.

b) Preliminary results

The distribution of Gelbstoff clearly shows the upwelling effect in the surface layer close to the African coast in the eastern part of the transect, (Fig. 80, right).

The complete transect depicts the increasing concentration of Gelbstoff with depth (Fig. 80, left). The nucleus of high Gelbstoff values that it is usually found over the slope and which is characteristic of the waters coming from the south was not found. This fact may indicate its absence, or alternatively that the distance between stations was not the adequate to resolve the presence of waters stemming from the south.

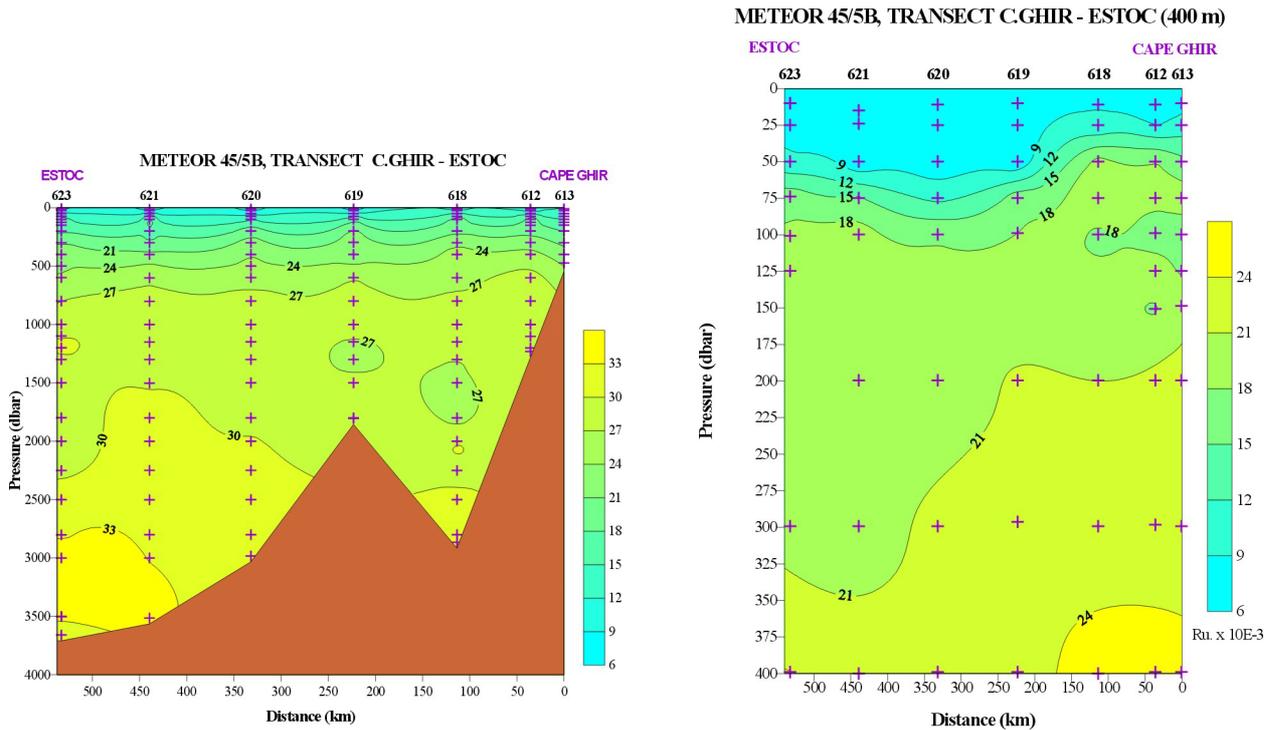


Fig. 80: Gelbstoff distributions along the transect from Cape Ghir to ESTOC; left-hand graph: entire water column; right-hand graph: water column to 400 m.

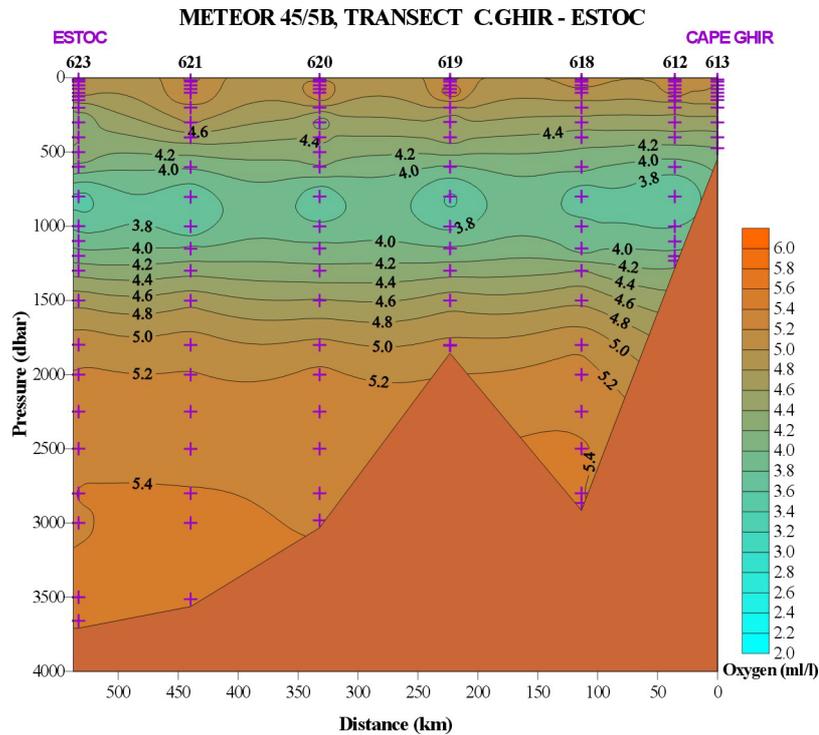


Fig. 81: Oxygen distribution along the transect from Cape Ghir to ESTOC.

Fig. 81 depicts the preliminary results of oxygen sampled along the Cape Ghir-ESTOC section, showing the normal structure encountered in this area, with a minimum between 800 and 1000 m along the whole transect. Slightly higher oxygen values were found in the Cape Ghir area, probably due to the presence of upwelled water.

5.6.9 Stable Nitrogen Isotopes of Dissolved Nitrate

(T. Freudenthal)

In order to investigate the stable nitrogen isotope ratio of deep water nitrate and the fractionation during assimilation, water samples for the measurement of stable nitrogen isotope ratios of dissolved nitrate ($\delta^{15}\text{N}_{\text{nitrate}}$) were collected. For each sample, about 1 l of sea water was filtered and stored frozen. Water for measurements of $\delta^{15}\text{N}_{\text{nitrate}}$ were taken at ESTOC (GeoB6013), at EBC (GeoB6034), and in the Cape Ghir filament area (GeoB6035, 6036, 6037, 6038).

5.6.10 Suspended Particulate Matter

(T. Freudenthal, C. Hayn)

Suspended particulate matter was sampled at 13 stations in the ESTOC/DOMEST area and in the Cape Ghir filament for the determination of particulate organic carbon (POC) and the stable nitrogen isotope ratio of suspended matter ($\delta^{15}\text{N}_{\text{suspended}}$). Either 2 l (for POC) or 5 l (for $\delta^{15}\text{N}_{\text{suspended}}$) were filtered from the Niskin bottles of the rosette through a 20 mm GF/F-filter. Filters were stored frozen for analysis on land. On 5 stations, larger particles were collected with vertical holes using a multiple closing net (Fa. HYDROBIOS, area 0.25 m²; mesh size 64 μm). The samples were fixed with mercury chloride and stored at 4°C. Net samples will also be used for the study of planktonic foraminifers and for geochemical analysis. Water was sampled for stable isotopes of oxygen and dissolved inorganic carbon. The latter samples were fixed with mercury chloride.

5.6.11 Trace Metal Sampling

(C. von Oppen, U. Schüßler)

Particle-water interaction is a key process in the biogeochemical cycling of chemical elements in the ocean. Uptake onto particulate matter and subsequent sinking mechanisms (scavenging) is the major control on the chemical composition of seawater. This mechanism maintains the concentrations of many elements in seawater rather low, many of which are, thus, called trace elements. The particulate matter itself consists of (i) suspended particulate matter (SPM) which is supposed to consist of almost non-sinkable biogenic and terrestrial particles with a large surface area and (ii) the relative fast sinking particles found in sediment traps, responsible for the vertical transport to the sediments. The comparison of the trace element composition and distributions in these three different phases (dissolved, SPM and trap material) are expected to provide important clues on transport and sorption mechanisms as well as on the general geochemical behavior of these elements in the ocean. Many of the trace elements studied here are essential for marine life, and thus also in the generation of the biogenically induced particle flux within the water column. These trace elements cover a broad range of chemical properties, enabling to study biogeochemical processes in greater detail. In an attempt to learn more about trace element relationships with organic carbon - the latter being a major biogenic constituent of sinking particles in the ocean - special emphasis is laid on sampling of suspended particulate organic carbon from different water depths.

Within the collaborative CANIGO project, the Marine Chemistry Department of the University of Bremen, Germany (UBMC), conducts studies on the biogeochemistry of a suite of trace elements. These elements exhibit different behaviour in the ocean, as can be seen, e.g. in the vertical profiles of their dissolved concentrations. In addition, input functions may vary strongly between individual elements. For

the CANIGO study area, atmospheric inputs of mainly Saharan origin are especially important. This material carries many trace elements with it, that are partially released upon deposition in the ocean. Scavenging of dissolved trace elements onto and incorporation of particulate trace elements into sinkable particles of mostly biogenic origin provides a pathway for the coupling of upper water processes and the deep sea.

Cruise leg M45/5b was dedicated to studying trace element cycling and particle-water interaction in the upper water column (<2000m). Samples were collected close to the ESTOC location and in the vicinity of Cape Ghir inside a filament as detected by satellite imagery. The purpose of this is to study any possible imprint of upwelling induced productivity changes on trace element signatures in both the suspended particulate phase as well as in the dissolved phase and to compare results to long-term data obtained at ESTOC. Besides, two other stations were occupied in order to address regional variability. Activities of the UBMC group encompassed the collection of samples for dissolved trace element analysis (by means of 12L GoFlo bottles attached to a rosette sampling device) as well as suspended particulate matter at different depth using *in-situ* pumps. The pumps were also used to collect large-volume samples for particulate organic carbon. All samples were collected rigorously applying clean sampling techniques to avoid contamination as far as possible. Sample processing was done under a clean bench inside a clean-air laboratory container onboard. Dissolved trace element samples were pressure-filtered with nitrogen gas through pre-cleaned 0.4 μm polycarbonate membranes directly from the sampling bottles. Besides trace element sampling, water samples were analyzed for nutrients as well as for oxygen. The macro nutrients nitrate, phosphate and silicate were determined according to standard photometric procedures. Dissolved oxygen was analyzed by titration using the Winkler method. The only trace element to be determined onboard was dissolved Aluminium (Al) by a fluorescence method. All other dissolved and particulate trace elements will be analyzed onshore. In addition, two multi-*in-situ* pumps were recovered along with C111 mooring north of Gran Canaria.

Preliminary results for the distribution of dissolved Al indicated seasonal variability at the ESTOC location. Al concentrations in autumn surface waters were rather low when compared to other seasons. The vertical profile in dissolved Al concentrations was somewhat untypical for this particle reactive element, since concentrations increased with depth down to about 800m where they agreed well with measurement obtained during other seasons. The depth interval influenced by waters of Mediterranean origin (ca. 1000-1250m) exhibited elevated Al concentrations with a complex pattern probably related to differences in salinity distribution. Together with data to be obtained in the on-shore laboratory, inter-elemental relationships will give further insight in the processes governing trace element cycling in the Canary Island region.

5.6.12 Carbon Dioxide in Sea-Water

(L. Laglera, M. González-Dávila)

In response to increased interest in global climate change and greenhouse warming, measurements of the marine carbon system (i.e. total CO_2 , TCO_2 , titration total alkalinity TA, pH and pCO_2) have been included in several global research programs such as the World Ocean Circulation Experiments (WOCE) and the Joint Global Ocean Flux Study (JGOFS). These programs include time series stations primarily designed to examine temporal variability and the mechanism controlling this variability. The Canary Islands Time series (ESTOC) is visited each month and the surrounding area approximately twice a year. Time series station data provide excellent opportunities to study the temporal variability of the carbon system at a single location over several years, while cruises around the ESTOC station will provide information about spatial variability of the carbon species in the area.

The main objective on this cruise was to study the spatio-temporal variability of the parameters which define the carbonate system in the water column. The parameters to be determined are pH and total alkalinity. Underway continuous $p\text{CO}_2$ were carried out in the DOMEST/ESTOC location and along the transect from Cape Ghir to ESTOC, together with air $p\text{CO}_2$ value (each hour). In addition, water samples for pH and titration alkalinity collected from surface to bottom were analysed on board within four hour of collection with a two-thermostatized ($25^\circ\text{C} \pm 0.1$) 200 ml titration cells with ROSS glass pH electrode and Orion double junction Ag, AgCl reference electrodes. The reliability of the titration systems was tested by determining the TA of Certified Reference Material for Oceanic CO_2 measurements (batch 35) provided by Dr. Dickson, Scripps Institution of Oceanography, San Diego. The results of these measurements indicate that high-precision measurements of TA ($\pm 1.2 \mu\text{mmol kg}^{-1}$) can be obtained. Photometric pH was determined by a stopped-flow system designed by this group by using a m-cresol purple sea-water solution as dye for the pH determination following the DOE (1994) SOP 6 for the analysis of the carbonate system variables of oceanic sea-water samples. Reproducibility better than 0.003 pH units has been obtained.

5.6.13 Primary Production Measurements

(S. Neuer, C. Hayn, J. Godoy, J. Langer, T. Freudenthal)

Phytoplankton primary production was determined by uptake of radiolabelled biocarbonate (^{14}C), dilution experiments and by the change of oxygen during incubation.

a) ^{14}C

Productivity experiments were carried out during M45/5b at three stations, Exp. 1 and 2 in the ESTOC area and Exp. 3 in the Cape Ghir filament area (Fig. 82). Water was inoculated with ^{14}C -bicarbonate (ca. $0.08 \mu\text{Ci/ml}$) and incubated *in situ* from dawn to dusk, following the standard JGOFS protocol (June 1994). Bottles were attached to a polyethylene rope and suspended from a surface drifter. Dark bottle values were not subtracted from light bottle values. At all stations, PP was highest in the surface layer, not in the depth range of the chlorophyll maximum due to light inhibition at these depths (close to 1% light level).

Chlorophyll was much higher in the filament area and PP values were higher up to a factor ten in the surface compared to the oligotrophic ESTOC/DOMEST area (Fig. 82).

c) Dilution experiments

Water for dilution experiments was incubated on deck for 24 h with water from 25 and 50 m during 24 h, always starting at dawn or at night before or after a ^{14}C -experiment. Light-levels at depths were simulated with neutral density screens, and the incubator was cooled with flowing surface sea-water. Dilutions of natural sea-water were incubated in 1 l poly-carbonate bottles. Phytoplankton growth and microzooplankton grazing rates were determined from the change of chlorophyll in the different dilutions by linear regression of the apparent growth rate in each dilution on dilution factor (LANDRY AND HASSET, 1982). Experiments were carried out in the DOMEST area on STA 593 (23 October), STA 606 (26 October), and in the Cape Ghir area (STA 617, 30 October).

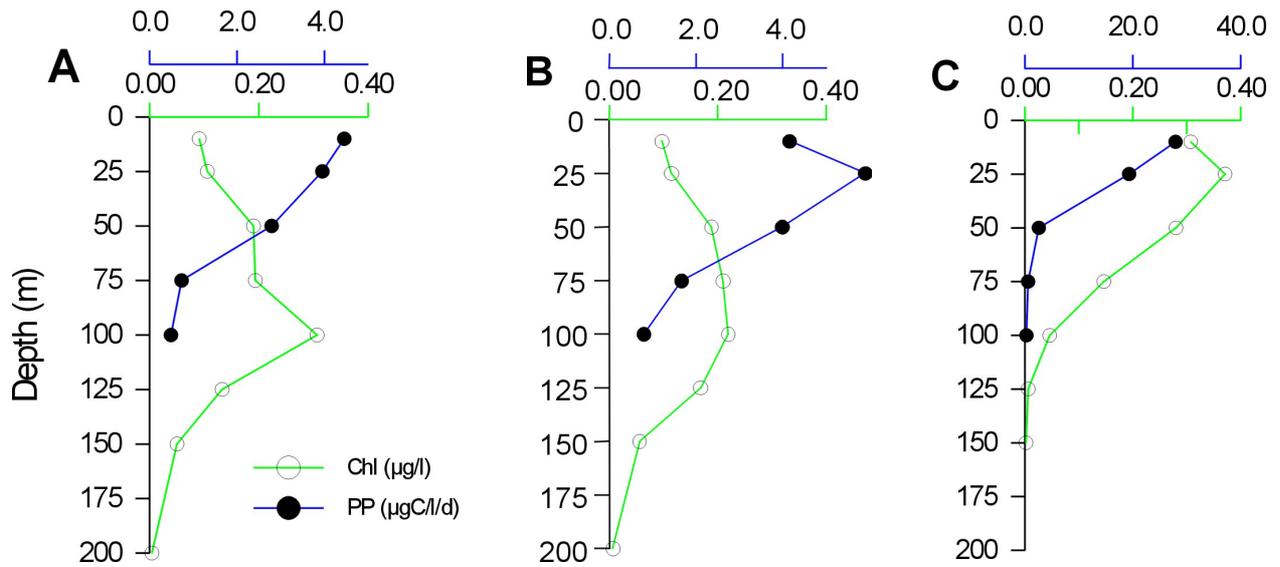


Fig. 82: Primary Production (upper x-axis) and chlorophyll (lower x axis) of three stations, in the ESTOC/ DOMEST area (A, STA 596, 24.10.1999; B, STA 607, 27.10.1999) and in the Cape Ghir Filament area (C, STA 614, 30.10.1999).

d) O₂ – incubations

O₂ - incubations were carried out under the same conditions and on the same stations (except STA 606) as the dilution experiments, with the change of oxygen determined in light and dark bottles of 250 ml volume. Incubation in the on-deck incubator lasted 12 h (between dawn and dusk). The change of oxygen in the dark bottles is due to respiration by the whole plankton community. The change in the light bottles reflects the production of oxygen by photosynthesis minus the loss due to respiration, and represents the net photosynthetic rate of the phytoplankton community. Gross photosynthesis can be determined by adding the loss of oxygen (calculated as hourly rate) due to respiration as determined from the dark bottles.