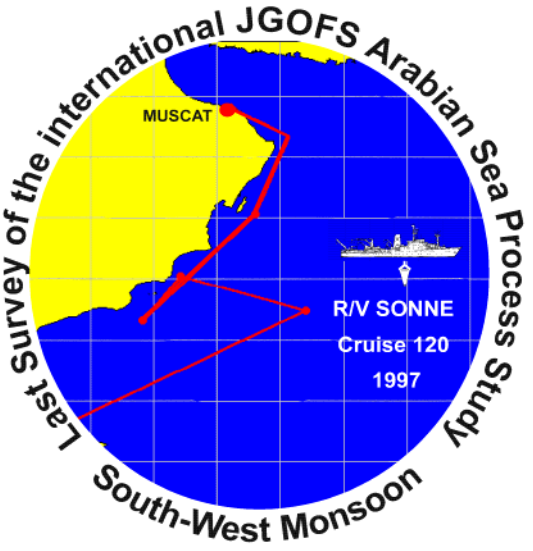
J G F S

Arabian Sea Process Study

CRUISE REPORT SONNE 120

12. June - 12. July 1997



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Institute for Marine Research, University of Kiel

1997

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Abstract

On the final cruise of the JGOFS process study in the Arabian Sea special emphasis was put upon the seasonal evolution of biogeochemical processes with the upswing of the SW-Monsoon.

The cruise leg SO 120 departed out of Muscat, Oman, on 12. June 1997 and sailed into Djibouti on 11. July 1997. Onboard there were an international team of scientists led by Prof. Dr. B. Zeitzschel.

Scientific work started close to the coast off Oman (18°N, 57°E) in an area of coastal upwelling. Hydrographic investigations enabled a detailed description of the physical environment in this area and were therefore a substantial precondition for a variety of biochemical studies. To accomplish the seasonal evolution of biogeochemical processes a satellite tracked drifting array with a sediment trap below the productive zone was deployed in this freshly upwelled water for 19 days. The drifter has been followed for 15 days meanwhile extensive water column sampling has been carried out. The research included the biochemical *level one* parameters which were designed for the documentation of nutrient conditions, biological stock parameters, fluxes in the epipelagial and the export production in the Arabian Sea during the SW-Monsoon.

The first results of the biochemical investigations were different to the situation expected. Despite the cold, nutrient rich water, phytoplankton concentrations remained surprisingly low. Small phytoplankton (< 2 µm) generally predominated with occasional patches of larger species (> 20 µm). This could be explained by the high abundance of mesozooplankton which would suggest that the studied system is controlled through top-down food web processes.

Zusammenfassung

Schwerpunkt der letzten Forschungsfahrt im Rahmen der JGOFS Prozeß Studie in die Arabische See war die Untersuchung der saisonalen Entwicklung der biogeochemischen Prozesse während des Aufschwungs des SW-Monsuns. Der Fahrtabschnitt SO 120 startete am 12. Juni 1997 in Muscat, Oman, und endete am 12. Juli 1997 in Djibouti. An Bord befand sich eine internationale Forschergruppe unter der Leitung von Prof. Dr. B. Zeitzschel.

Die Arbeiten begannen in der Region des Küstenauftriebs vor der Küste von Oman (18°N, 57°E). Hydrographische Untersuchungen erlaubten dabei eine detaillierte Beschreibung der physikalischen Parameter in dieser Region und stellen damit eine wesentliche Voraussetzung für die vielfältigen biologisch-chemischen Arbeiten dar. Zur Beschreibung der saisonalen Entwicklung der biogeochemischen Prozesse wurde ein Satelliten geortetes Driftsystem mit einer Sinkstoffalle unterhalb der euphotischen Zone in die Auftriebsregion für 19 Tage ausgesetzt. Das Schiff folgte dem Drifter 15 Tage, während intensive Wassersäulenbeprobungen stattfanden. Ziel der biologisch-chemischen *level one* Parameter war die Dokumentation der Nährstoffverhältnisse, der biologischen Bestandsgrößen, der Stoffumsätze im Epipelagial und der Exportproduktion im Arabischen Meer während des SW-Monsuns.

Die ersten Ergebnisse unterscheiden sich stark von der Situation, die erwartet wurde. Obwohl der Küstenauftrieb charakterisiert war durch kaltes, nährstoffreiches Wasser, blieben die Phytoplanktonkonzentrationen erstaunlich gering. Kleine Phytoplankter dominierten in der Regel die Phytoplanktongemeinschaft, wobei größere Arten nur gelegentlich auftraten. Die Abundanz des Mesozooplanktons und deren Freßaktivität legt die Vermutung nahe, daß dieses System *top-down* gesteuert wurde.

ERRATUM

The first paragraph appearing at the beginning of the chapter **5.6 Planktological studies** on page 25 should be substituted. The context should read as printed below.

5.6 Planktological studies (C. Sellmer, K. von Bröckel, I. Kriest, K. Nachtigall, P.Fritsche, E. Stangeew)

The planktological working group studied characteristic coastal upwelling (eutrophic - warm water) and open ocean features (upwelling - cold water and/or oligotrophic - warm water) in the western Arabian Sea during the beginning of the SW-Monsoon (June/July). Different biological, chemical, and physical properties of the pelagic system were determined during two drifting stations as well as on several oceanic stations.

The cruise was dominated by different working strategies:

1) To find a filament reaching from the coastal upwelling into the open ocean, several transects have been covered and sampled. Together with informations from satellite images of the **S**ea **S**urface **T**emperature (SST), continuous determination of the partial pressure of CO_2 (pCO_2) in the surface sea water and atmosphere (IFBM, Hamburg), as well as the continuous registration of the fluorescence, such a filament could be detected. The examination comprised station work (CDT casts, net hauls) as well as underway sampling.
2) After discovering a filament, a drifter (description below) was deployed right in the assumed center and followed. During this time, an extensive water-column sampling has been carried out mostly in the upper 100 m (depending on the water depth).
3) After following the drifter for eleven days in a row, it was left alone. The ship headed towards the open ocean to determine conditions there. Unfortunately, due to pretty bad weather conditions, only ten stations could be sampled within four days with casts down to 2500/4500 m.
4) The ship returned to the drifter and the cruise finished after additional four days of intensive sampling at the drifting station.

During the cruise two drifting stations - eleven and four days - were carried out close to a drifting array deployed for 19 days in a row. The drifter consisted of a spar-buoy with benthos spheres for flotation and an automatic Kiel sediment trap. Furthermore, the drifter was equipped with an inclinometer attached to the trap and current meters right above and below the trap to obtain informations about the movement and the position of the trap relative to the water. Positioning of the drifter was done with ARGOS transmitters as well as by visual objects (flash and banner).

1 Research objectives

1.1 Introduction

Within the **J**oint **G**lobal **O**cean **F**lux **S**tudy program (JGOFS), Prof. Dr. B. Zeitzschel (Institute for Marine Research, Kiel) conducted the second JGOFS-Indik cruise (So120). This cruise took place in the western Indian Ocean, with the major work within the Arabian Sea (see Fig. 1). The cruise began on June 12th 1997 in Muscat (Oman) and ended on July 12th, 1997 in Djibouti. During this leg at the high productive SW-Monsoon period biological, chemical and hydrographical measurements were carried out in the context to investigate the relations between climate changes and the coastal oceanic eco-system. With special emphasis the processes of the oceanic carbon cycle has been studied between the Oman coast (18°N, 57°E) and the open Arabian Sea (16°N, 62°E). The regions of main interest was:

⇒ the region of coastal upwelling in front of the Oman coast and

⇒ the region, which is directly influenced by the Findlater Jet in the open Ocean (16°N, 62°E).

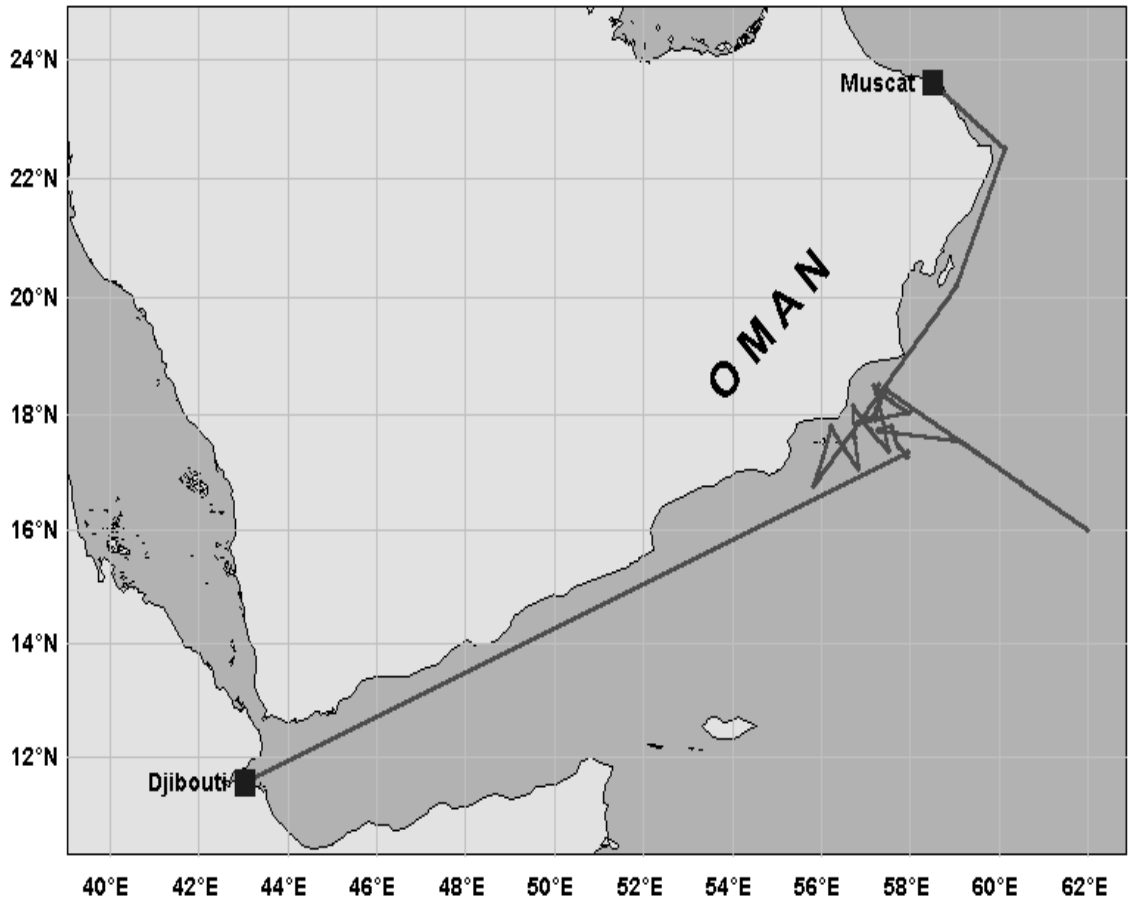


Fig. 1: *Cruise track of SONNE cruise 120*

1.2 JGOFS Project

The **J**oint **G**lobal **O**cean **F**lux **S**tudy (JGOFS), is a long-term international program investigating the fate of carbon in the ocean, atmosphere and sediments of the most recent past. The central aim of JGOFS is to improve the understanding of the global ocean carbon cycle. The Arabian Sea was selected as one of four major study areas where international coordinated studies during the years 1994 -1997 took place (SCOR, 1995). For this international project, several research cruises from different countries took place in the Arabian Sea in 1995. The German contribution to this project took place during 2 legs (M32/3 and M32/5) in 1995 and during 3 legs (So117, So119 and So120) in 1997 (see Tab. 1). Major work during the leg So120 was the investigation of processes of particle formation and modification during the SW monsoon.

Tab.1: *Legs and chief scientis of SONNE cruise*

Leg So117

26.02.1997 - 30.03.1997, Cochin/India - Muscat/Oman
Chief scientist: Prof. Dr. W. Balzer

Leg So119

12.05.1997 - 11.05.1997, Muscat/Oman - Muscat/Oman
Chief scientist: Prof. Dr. V. Ittekkot

Leg So120

12.05.1997 - 12.06.1997, Muscat /Oman - Djibouti
Chief scientist: Prof. Dr. B. Zeitzschel

2 Participants

Tab. 2: *Participants of SONNE cruise So120*

NAME	RESEARCH FIELD	INSTITUTE
1. Zeitzschel, Bernt, Prof. Dr.	Chief Scientist	IFM-K
2. Bange, Hermann	Biogeochemistry	MPI
3. Becker, Stefan	Marine Geology	GPI
4. Burkill, Peter H.	Pico- und Nanoplankton	PML
5. Dencker, Felix	Marine Optics	UOL
6. Edwards, Elaine	Pico- und Nanoplankton	PML
7. Fritsche, Peter	Planktology	IFM-K
8. Irwin, Brian D.	Remote Sensing	BIO
9. Krehl, Regina	Microbiology	IFM-K
10. Kriest, Iris	Modelling	IFM-K
11. Lendt, Ralf	Marine Chemistry	IFBM
12. Mitzka, Thomas	Data management	IFM-K
13. Nachtigall, Kerstin	Planktology	IFM-K
14. Rick, Johannes-Josef	Marine Botany	IFM-K
15. Sellmer, Claudia	Planktology	IFM-K
16. Sommer, Ulrich, Prof. Dr.	Marine Botany	IFM-K
17. Spietz, Matthias	Marine Chemistry	IFBM
18. Stangeew, Elena	Planktology	IFM-K
19. Ullrich, Sören	Microbiology	IFM-K
20. von Bröckel, Klaus	Planktology	IFM-K
21. Waniek, Joanna	Oceanography	IFM-K
22. Zeller, Ute	Planktology	IFM-K
23. Zeltner, Alexandra	Foraminifera	GPT
24. Zwierz, Marek	Oceanography	IFM-K

Participating Institutions

IFM-K	Institut für Meereskunde an der Universität Kiel Düsternbrooker Weg 20 24105 Kiel - Germany
IFBM	Institut für Biogeochemie und Meereschemie Bundesstraße 55 20146 Hamburg - Germany
GPT	Geologisch-Paläontologisches Institut der Universität Tübingen Sigwartstr. 10 72076 Tübingen - Germany
GPI	Geologisch-Paläontologisches Institut der Universität Kiel Ludwig-Meyn-Straße 10 24118 Kiel - Germany
MPI	Max-Planck-Institut für Chemie Saarstraße 23 55122 Mainz - Germany
UOL	Carl von Ossietzky Universität Oldenburg, Fachbereich 8, Physik, Ammerländer Heerstraße 114-118 26129 Oldenburg - Germany
BIO	Bedford Institute of Oceanography, Darmouth Dept. of Fisheries and Oceans PO Box 1006 Dartmounth, Ns.
PML	Plymouth Marine Laboratory, Plymouth Prospect Place, West Hoe Plymouth PL1 3 DH United Kingdom

3 Research programs

The main interest during the cruise So120 was the measurements of the fast temporal variability of the leading biological, chemical and hydrographical parameters during the SW-Monsoon (June/July) in the Arabian Sea. For documenting vertical particle fluxes out of the productive zone, drifting sediment traps was deployed in the centre of a cold water structure and followed for several days. During this time extensive water-column sampling with a combined CTD- water bottle rosette with additional sensors (oxygen, fluorescence) was carried out in the uppermost 200 m as well as down to 2000 m and/or close to the bottom for (**1**) nutrients, oxygen, phytoplankton composition and biomass as well as for total and new production determination; (**2**) distribution of nanoflagellates and investigation of the role of autotrophic calcite-forming coccolithophorids in the carbon dioxide cycle; (**3**) distribution and composition of autotrophic pico- and nanoplankton. Following the extensive water- column sampling, net sampling, for mesozooplankton and planktonic foraminifera stock as well as for grazing experiments was performed. Furthermore the quality and quantity of carbonaceous and silicious flora and fauna of the productive zone in the Arabian Sea has been investigated through net and water samples from the productive- and export zone. Further main emphasis was stressed on the temporal and spatial distribution, abundance and biomass of bacteria, picocyanobacteria and the bacterial net secondary production.

The aim of the IfBM-Group Hamburg, was to describe the spatial distribution and the temporal variability of the four parameters in the oceanic carbonate system: total dissolved inorganic carbon (TCO_2), total alkalinity (TA), partial pressure of CO_2 (pCO_2) in the surface seawater and atmosphere. Emissions of the climatically relevant trace gases by continuous measurements of atmospheric and dissolved nitrous oxide (N_2O) and methane (CH_4) were performed by the MPI-Group, Mainz.

Furthermore, measurements to verify the distribution of natural radionuclides in the water- column and relate them to the measurements of the moored sediment traps (Prof. Ittekkot) were carried out by the GPI-Group, Kiel.

Dissolved and particulate organic substances were investigated by bio-optical measurements of the main phytoplankton pigments and the fluorescence derivatives of the „yellow substance“. Moreover measurements of the radiation field in the water-column were performed with lightsensors.

In anticipation and during the SONNE-expedition So120 (June 12th - July 12th, 1997) satellite-data of the **S**ea **S**urface **T**emperature (**SST**) were continuos examined with regard to upwelling regions. The purpose of this data-analysis were to get an idea about the frequency of filaments formation as well as their spatial variability.

4 Narrative of the Cruise

The R.V. SONNE departed from Muscat/Oman on June 12th, and sailed to the first planned station at 17°N, 56°E. One station for testing the different instruments were successfully carried out one day after the equipment had been unpacked and installed in the laboratories. On June 14th the research program began with course to the first main research area, the upwelling region in front off the coast of Oman. On this area two different grids were performed from 16°45´N, 55°50`E till 17°57´N, 57° 23´E with a couple of CTD and hydrocast stations as well as parallel surface water probing drawn at 6.5 m depth to study the horizontal distribution and variability's of chemical and biological parameters. This data together with the satellite images of the **S**ea **S**urface **T**emperature (**SST),** continuous determination of the partial pressure of CO_2 (pCO_2) in the surface sea water and atmosphere (IFBM, Hamburg), as well as the continuous registration of the fluorescence, provide us with the necessary information about the upwelling region off the coast of Oman and the spatial variability of filament formation at the beginning of our drift station in the centre of the cold water structure.

At the drift station the scientific aim was to analyse the fast temporal variability of the vertical particle export out of the euphotic zone during the SW-Monsoon. Drifting sediment traps (equipped with fluorometer, inclinometer and currentmeters) were deployed below the euphotic zone (30-50 m). The ship followed it at the first drifting station for eleven days and respectively for four days at the second (Fig. 2). During this time extensive water-column sampling with a combined CTD- water bottle rosette as well as net samples were performed for the analyses of the different biological, chemical and hydrographic parameters.

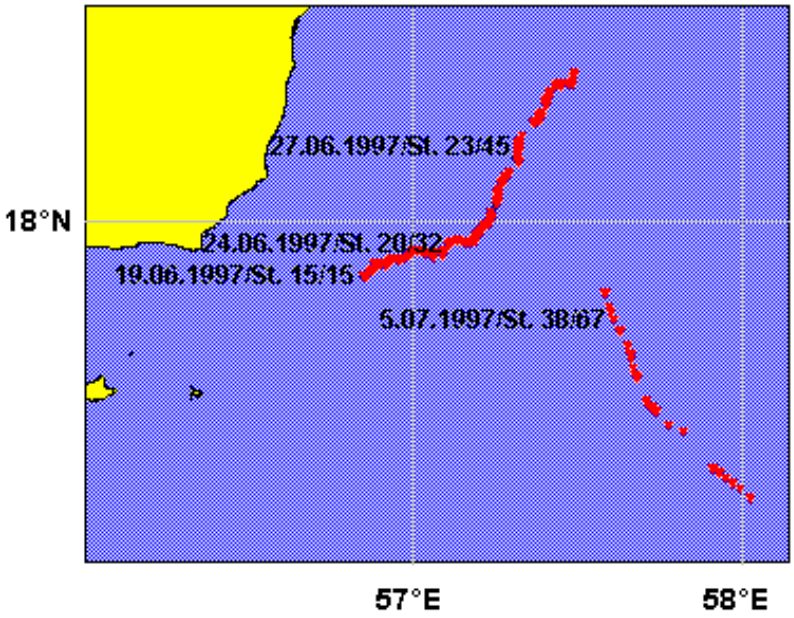


Fig. 2: *Drifting track over the cruise*

After 11 days we left the drifter alone and took direction to the WAST-Station to verify the distribution of natural radionuclids (^{234}Th, ^{230}Th, ^{232}Th, ^{210}Pb, ^{210}Po) in the water- column and relate them to measurements of the moored sediment traps from Prof. Ittekkot (IFBM) located at the WAST-Station (16° 20`N, 60° 30`E). During five days we repeated the transect from two years ago. Unfortunately, due to bad weather conditions, only sampling of the water-column from a combined CTD- water bottle rosette could be performed down to 2500/4500 m for radionuclids, total dissolved inorganic carbon (TCO_2) and total alkalinity (TA), as well as the JGOFS *level one* parameters and P/I measurements.

During the transects and CTD stations, surface water probing from a pumping system (underneath the ship in 6.5 m depth) were conducted every 10 to 30 nm to get information about the large scale horizontal distribution of nutrients and Chl *a*.

On 5th July we left this transect and set a course towards the coast of Oman, were, based on satellite information of the **S**ea **S**urface **T**emperature (**SST**), we expected to enter in a coastal upwelling filament (see Fig. 3). The main interest was focused on a detailed investigation of the band of cold water structure. Underway sampling (each 5 nm) from the pumping system was carried out for chlorophyll and nutrient analyses as well as XBT measurements. Furthermore the continuous measurements of partial pressure of CO_2 (pCO_2) in surface sea water and fluorescence were used to establish the cold water mass in this region. On 4th July at 01:00 (UTC) we found a 50 sm large band of cold water near the coast of Oman - characterised by a drop of 7°C in the sea surface water temperature together with an increase in nutrient concentrations and in the fluorescence. At 17° 42´N, 57° 17´E intensive biological, chemical and hydrographic measurements were performed on this upwelling filament. After intense examinations we left this region and took direction to the drifting sediment trap which floated into a south easterly direction since our last drift station.

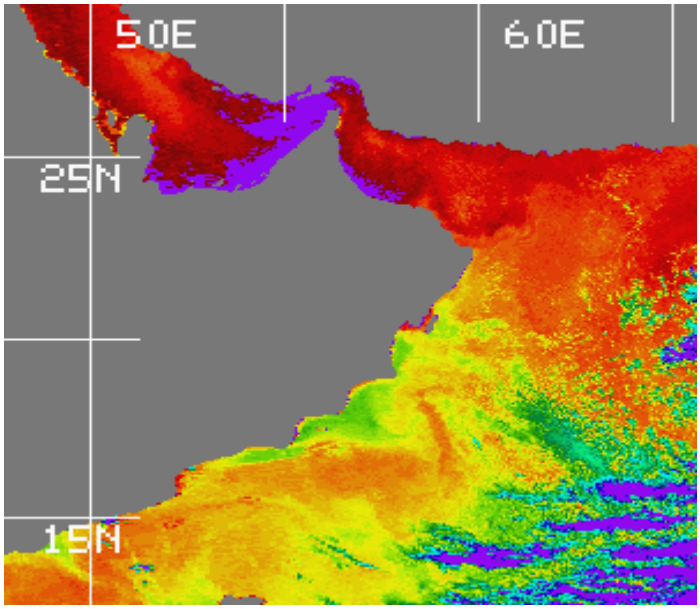


Fig. 3: Sea Surface Temperature (SST) from 03. July 1997

On July 4 we recover the drifting sediment trap after four days and deployed it again. The following four days were performed like the beginning of our drifting study where the ship over the course of 24 hours, followed it. Extensive water-column sampling as well as net sampling and bio-optical measurements were done.

On July 7 at 19:00, with repeated XBT´s measurements, we finished our investigation at 17°N, 57°E and took course towards Djibouti. In the noon of July 11, the R.V. SONNE arrived in Djibouti, and the cruise ended after a detailed investigation in the upwelling region of the coast of Oman and in the central part of the Arabian Sea.

5 Sampling Strategies and Preliminary Results

Hydrography (T.Mitzka, J. Waniek, M. Zwierz)

During the Sonne cruise So120 from Muscat to Djibuti hydrographic measurements were carried out in the region of the coastal upwelling off the Arabian Peninsula and in the region influenced by the Findlater Jet (Fig. 4a). The standard sampling device was a combined CTD water sampler with 24 10l Nisken bottles and additional sensors for oxygen and chlorophyll a fluorescence. In addition diurnal changes in the mixed layer depth and their forcing functions (solar insulation, air temperature and wind stress) were monitored by CTD device and shipborne sensors. The hydrographic measurements were carried out to estimate the relevant depths for biological and chemical probing and for determination of the physical properties (depth of the mixed layer and oxygen minimum, distribution of temperature and salinity). Water sampling was concentrated on the euphotic zone (maximal down to 200 m water depth) for characterisation of the distribution of relevant physical, chemical and biological properties within the epipelagic zone and however if different vertical structures observed with the sensors suggest interesting signals in deeper water layers, the sampling was extended. The spatial and vertical variability of the temperature field between the CTD stations were investigated by XBT drops (see Fig. 4b, Expandable Bathythermographs; upper 1800 m of the water column).

The investigations started with a combined CTD and surface sampling survey, which followed our drifting system, heading to the north. Near the coast a wide region with less sea surface temperatures (Fig. 5a) compared to the surrounding areas south of 17°30‘N and north of 19°N, was observed in the continued temperature registrations with shipborne sensors in 6.5 m depth.

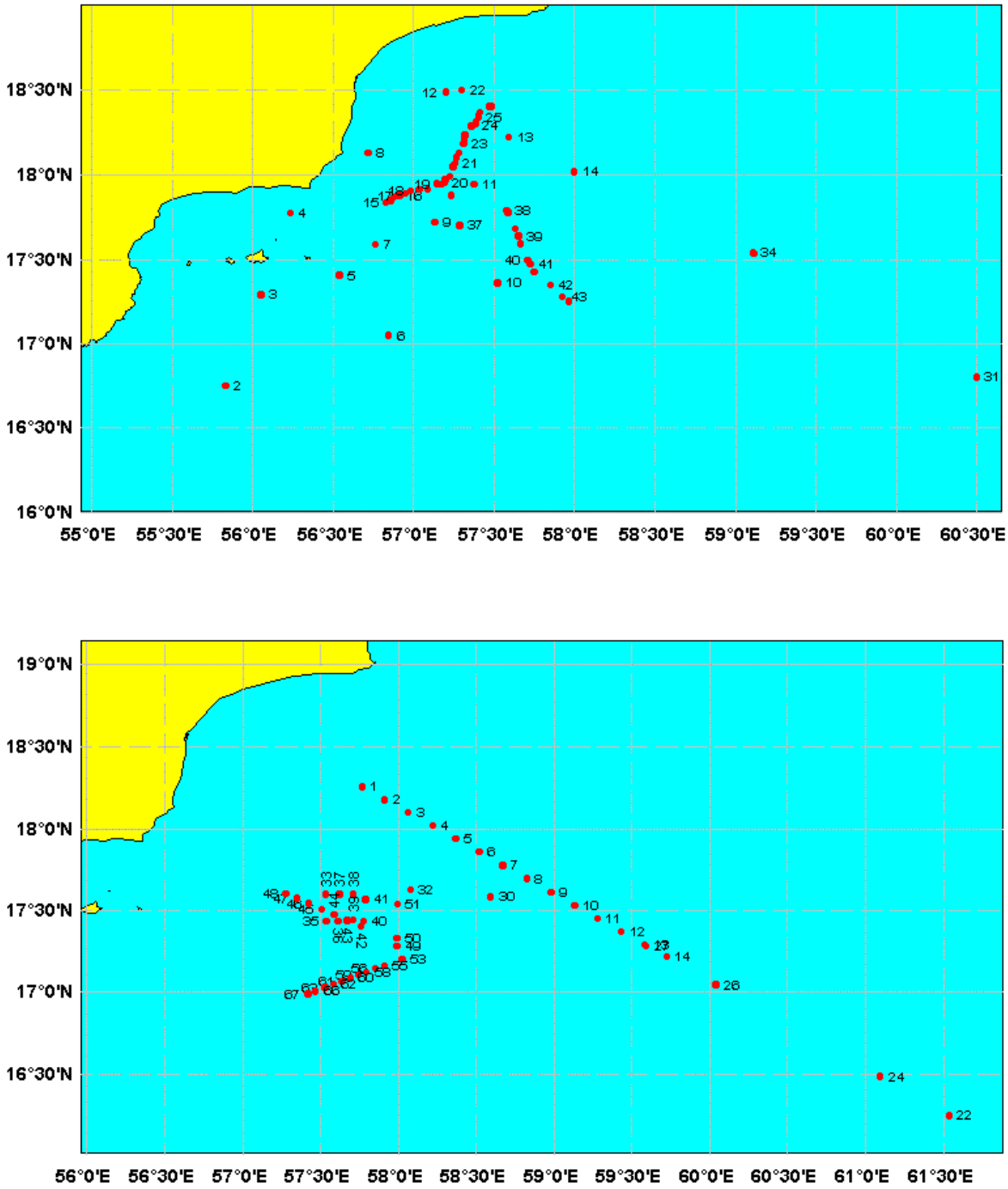


Fig. 4: *Research area of the JGOFS Cruise from Muscat to Djibutti (12 June – 12 July 1997) in the Arabian Sea during SW-Monsoon:* ***(a)*** *CTD stations of Sonne cruise So120 and* ***(b)*** *distribution of XBT drops of Sonne cruise So120*

The area was characterised by less temperatures (<24.5°C) at the sea surface extended from the coastal waters between 17°30‘N, 56°E and 19°N, 57°30‘E and was dominated by the classical coastal upwelling near to the coast. The cold surface water branch propagated in south-eastward direction and was also clearly evident at the surface offshore at 58°30‘E (see Fig. 5a/b). The temperature gradients between the

centre of the cold water body at surface to both sides reached 10°C. The strong temperature gradients at sea surface between 56°E and 59°E were connected to relative high nutrient concentrations and upwelling structures in the horizontal/vertical distribution of the physical parameters in the water column below.

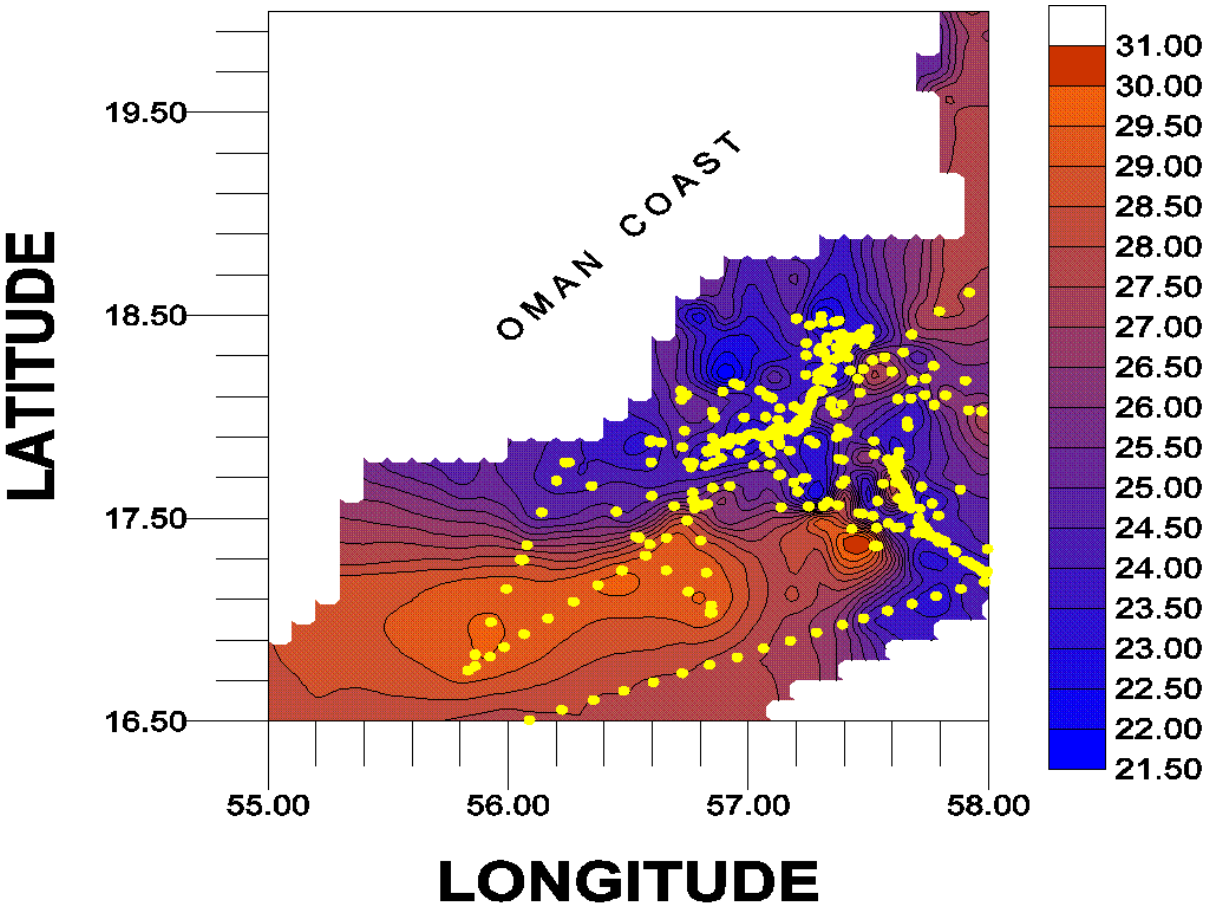


Fig. 5a: *Distribution of the Sea Surface Temperature (SST, °C) in the investigation area during the So120 cruise; uncalibrated data measured by shipborne sensors in 6.5 m depth. Yellow dots denote 5 min avarages of the continued measurements and of SST*

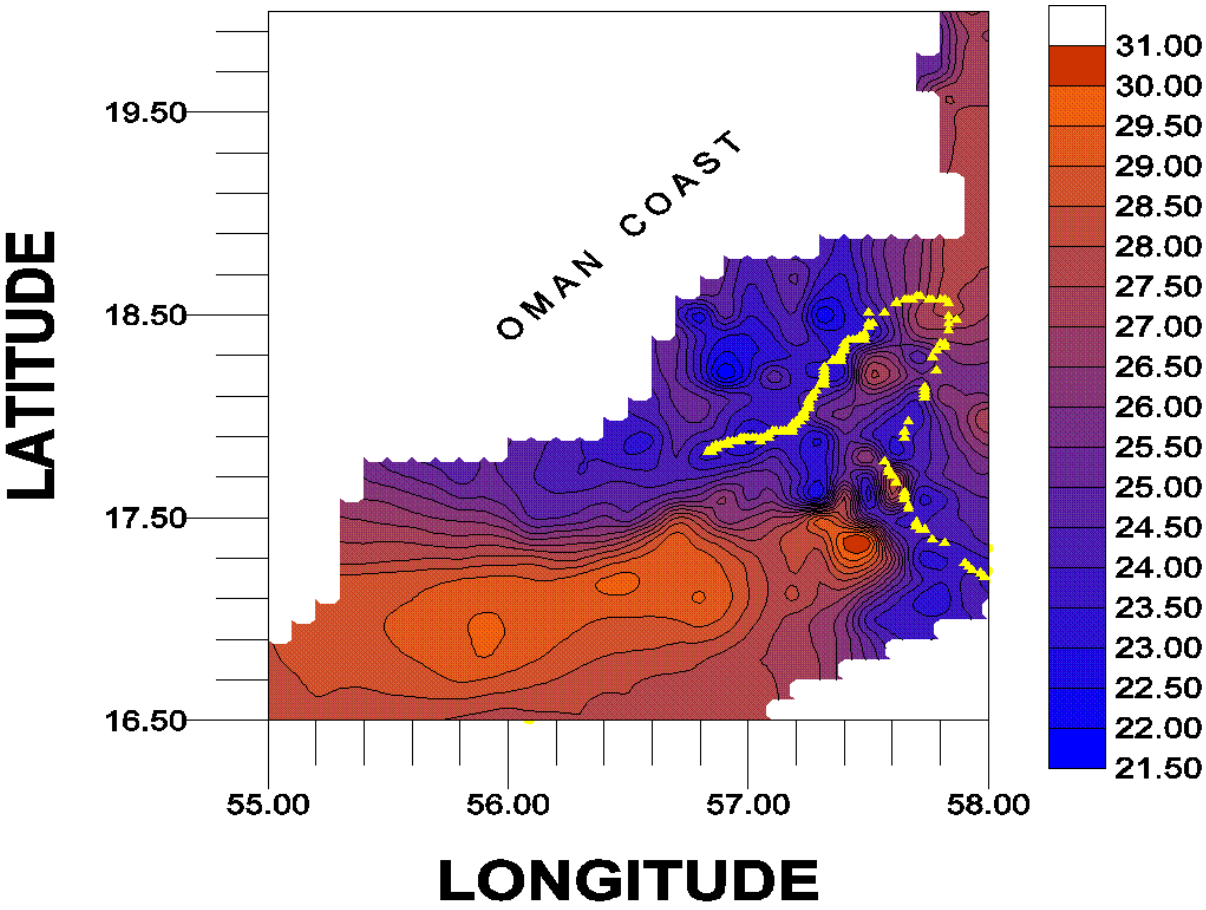
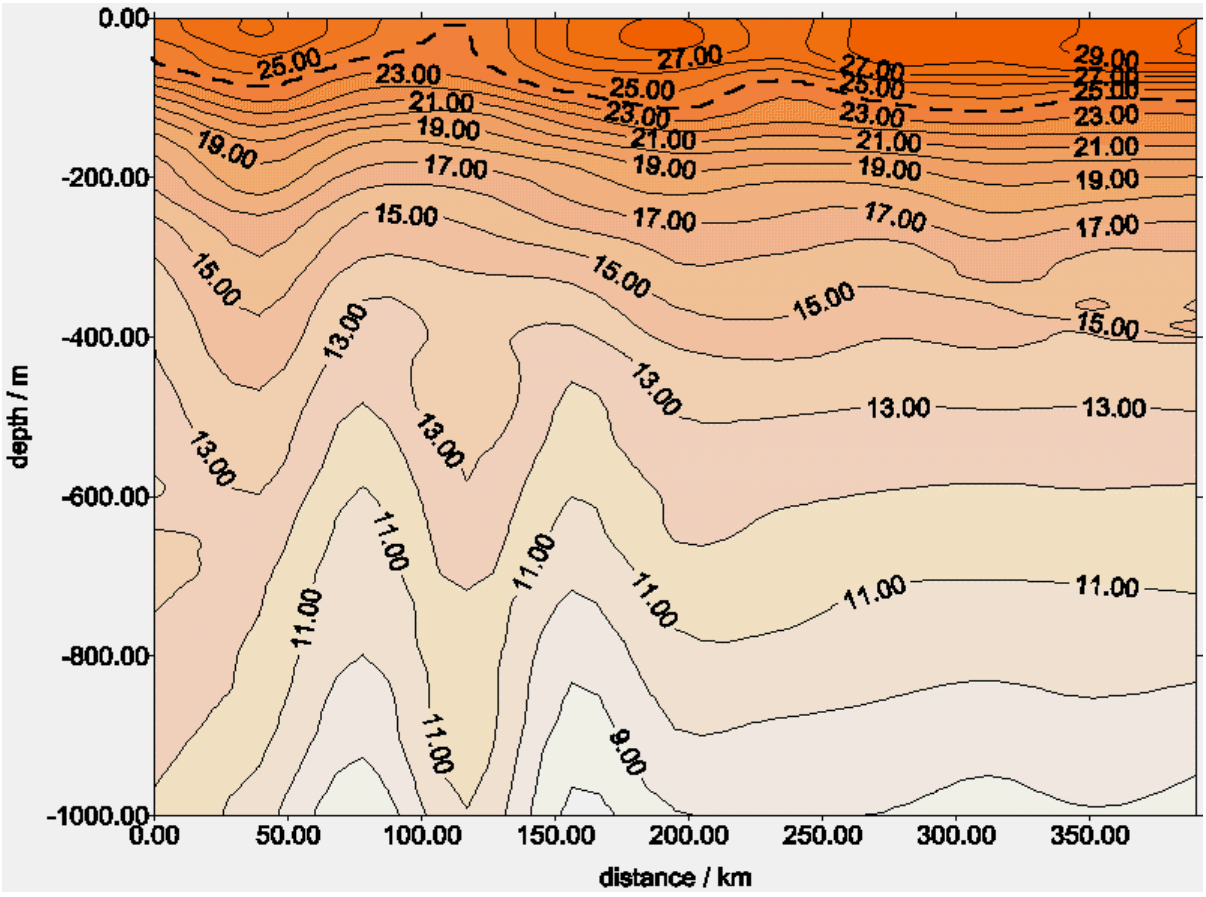


***Fig. 5 b**: Distribution of the Sea Surface Temperature (SST, °C) in the investigation area during the So120 cruise; uncalibrated data measured by shipborne sensors in 6.5 m depth with the trajectory of the drifter deployed during the cruise; green triangles denote the positions of the drifting system from 26.06.1997-07.07.1997*

The vertical temperature distribution along the XBT section (XBT1-XBT14, see Fig. 4) is typical for a region in the tropical part of the ocean, with some interesting features in the upper 200 m of the watercolumn (Fig.6a and b). The surface layer down to 200 m is occupied by warm water masses with temperatures between 30°C at surface and 17°C in 200 m depth and is bounded downwards by strong seasonal gradients in 200 m. In a distance of 100-150 km from the first XBT station a branch of colder upwelled water is evident at the surface, which indicates a part of the filament. The sea surface temperature reaches 24°C compared to 29°C in surrounding area. The vertical temperature distribution from 200 m depth down to 1000 m shows a decrease in the temperature signal that reaches values between 9 -10°C in 1000 m depth (Fig. 6a/b). Eastwards the variability and the gradients are smoothed and the watercolumn is more homogeneous.



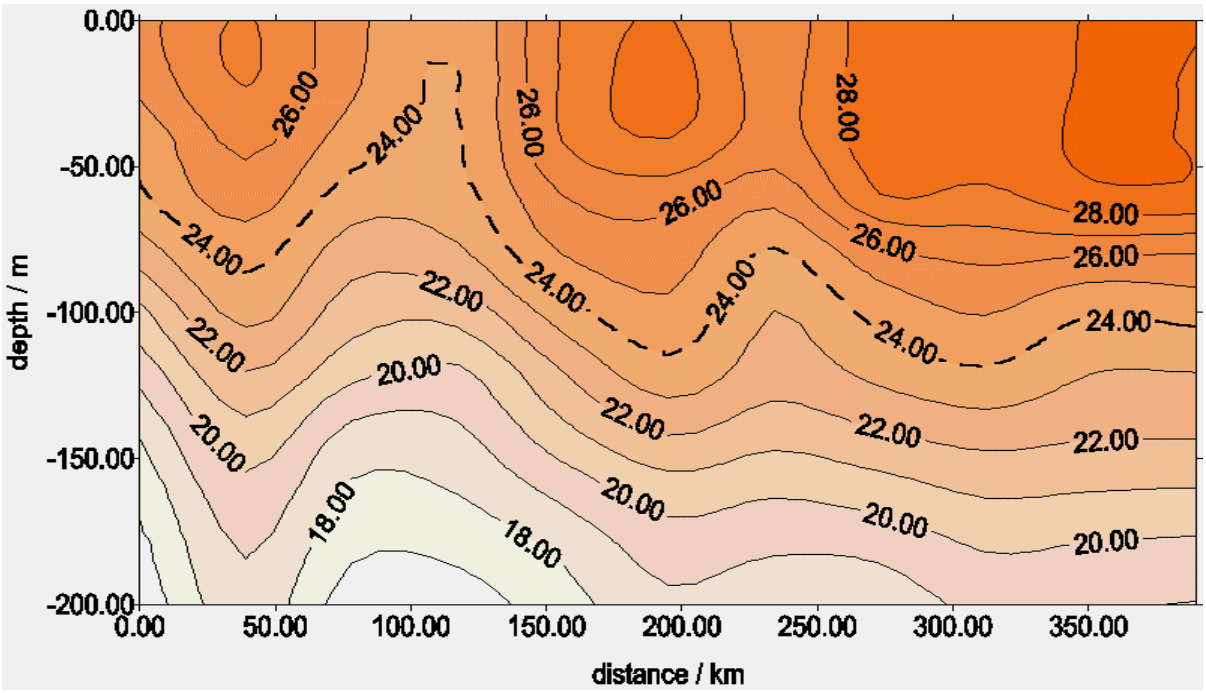


Fig. 6: *Temperature section measured during So120 from XBT 1 to XBT 14. The distance is calculated relative to the first XBT; uncalibrated data from XBT drops; for positions of the XBT profiles see Fig. 4;* ***(a)*** *vertical temperature distribution in the upper 1000 m and* ***(b)*** *the upper 200 m of the water column*

5.2 Optical measurements during So120 (J.Waniek)

The aim of the optical investigations during Sonne cruise So120 during south west monsoon 1997 was to describe the mesoscale structure of the optical variables (photosynthetic available radiation (PAR), light availability) in the water column. Optical measurements were carried out with a bio-optical sensor system. This device measures p, T, S (shallow water FSI-CTD, max. depth 150m) and the photosynthetic available radiation (PAR, 4π, 2π-upwelling, 2π-downwelling). In addition chlorophyll a and phycoerithrin fluorescence, the spectral composition of light between 400 and 700 nm and the oxygen saturation were measured. During the cruise the optical measurements were carried out on 23 stations, every day at noon. Reference measurements of incident radiation on board of the vessel completed the optic program. Optical data will be used with data on the vertical distribution of phytoplankton biomass, production and experimental measurements of optical parameters (PxI).

Photosynthetic available radiation (PAR) measurements during So120

During the cruise PAR measurements were carried out on 23 stations in time where the ship is following our drifting array. The PAR measurements at station 4 (17°45.7 N, 56°13.8 E) shows a maximum of 2500 mW/m2*nm at surface (1m) for the wavelength 400-450 nm and a drastical decreasing of the PAR signal because of absorption in the remaining wavelength range between 450-700 nm. At this station the phytoplankton population in the upper meters of the watercolumn was dominated by diatoms and the Chl a - maximum was observed near the surface (surface-20m). Below the surface in depths intervall 5-20 m a second PAR maximum was observed (minimum of absorption), with values >1000 mW/m^2*nm between 450-500 nm. From 20 m depth to the bottom (46 m) the PAR signals show no significant differences (Fig. 7) and reached values $\leq$ 500 mW/m^2*nm. The relative PAR intensity calculated for the station relative to the 1m values shows values higher 100% in depths between surface and 11 m for the wavelength 450-550 nm. The higher values (> 100%) in the upper 11 m of the water column and the re-increase of the relative PAR values for the remaining wavelength range shows that the light conditions have changed during the measurements. Therefore further calibration with the incident radiation measured as reference values on board the vessel has to be carried out and will be included for final analysis of the data set. In the remaining water column, below 20 m depths the relative PAR signal is dominated by absorption (Fig. 8).

The PAR signal measured on station 25 by 18°24.1N, 57°28.5 E (Fig. 9) shows different features compared to station 4: a very high intensity (values 4000-7000 mW/m^2 nm) in the upper 10 m of the water column. Below the 20 m depth a decrease in the light intensity in the whole wavelength range is evident. The most drastical change in the intensity of the measured PAR signal is evident below those depth, where the Chl *a* - maximum (20-30 m) was observed. From 40 m to 100 m depth the differences in the PAR intensity are very small and the values in the whole wavelength range reached similar values (<500 mW/m^2nm). The relative intensity of the PAR signal, calculated relative to the PAR signal in 4 m depth (100%) shows a very strong absorption of the PAR underneath 20 m (Fig.10). The relative PAR intensity between 400-450 nm and 550-700 nm reached values below 5% of the surface intensity and between 450-550 nm the relative PAR intensity reached 10% of the surface intensity.

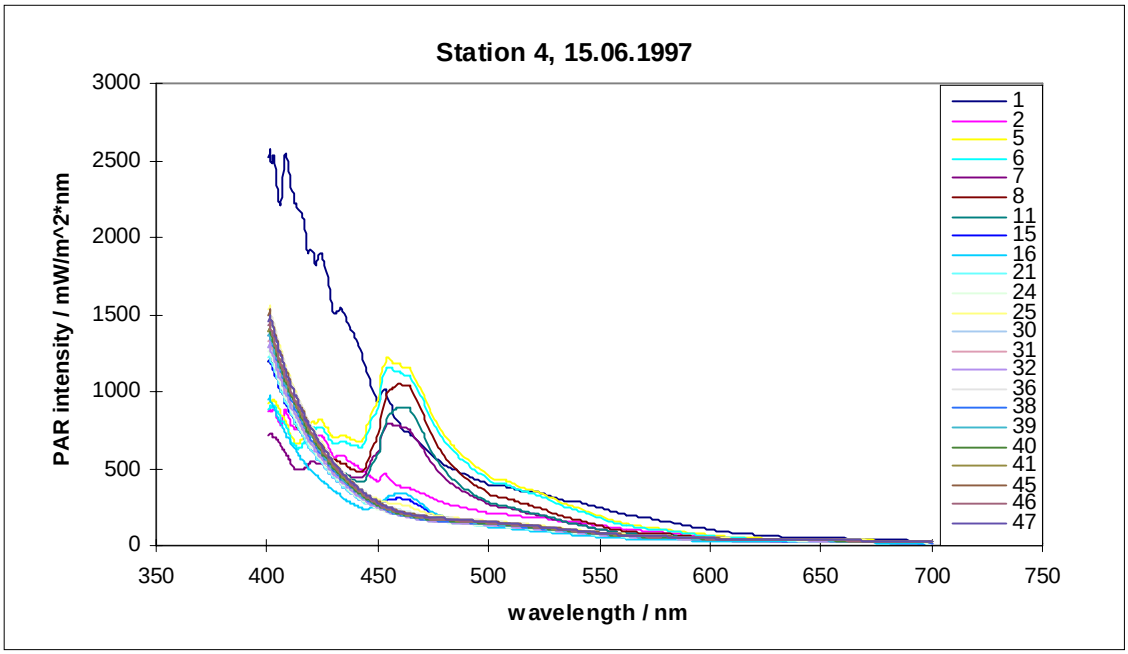


Fig. 7: *Distribution of the photosynthetic available radiation (PAR, wavelength 400 nm-700 nm) in the water column for several depths; Station 4, on 15.06.1997 at 17°45.7 N, 56°13.8 E*

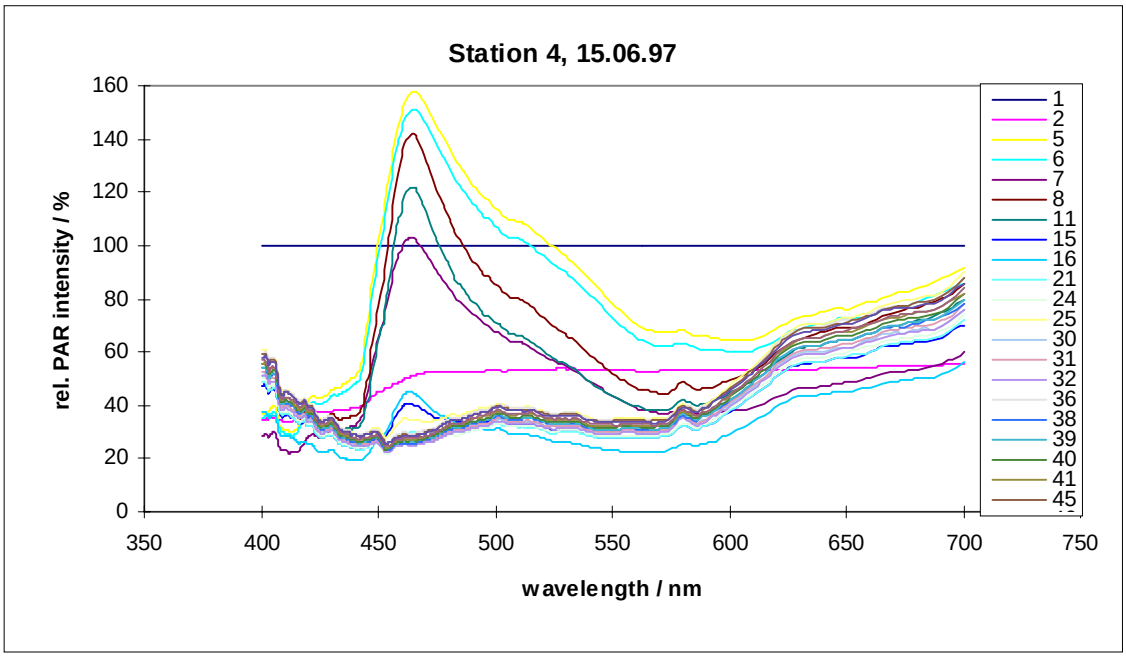


Fig. 8: *Relative intensity of the photosynthetic available radiation (PAR, wavelength 400nm-700 nm) in the water column for several depths calculated relative to the „surface“ values measured in 1 m depth (100%); Station 4, on 15.06.1997 at 17°45.7 N, 56°13.8 E*

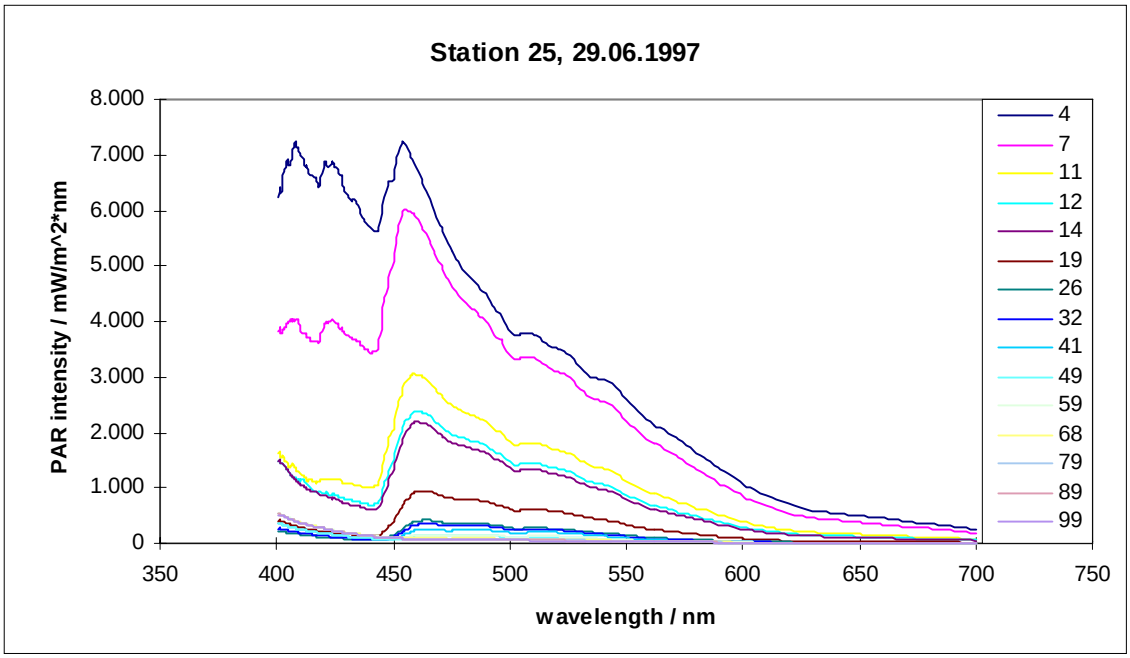


Fig. 9: *Distribution of the photosynthetic available radiation (PAR, wavelength 400 nm-700 nm) in the water column for several depths; Station 25, on 29.06.1997 at 18°24.1N, 57°28.5 E*

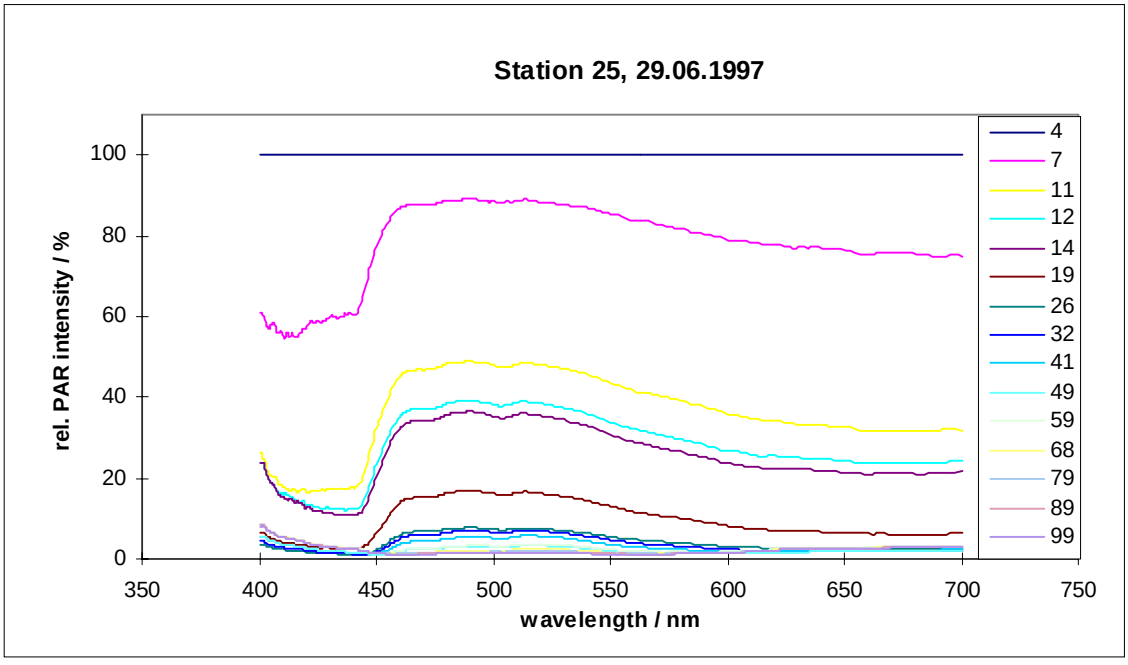


Fig. 10: *Relative intensity of the photosynthetic available radiation (PAR, wavelength 400 nm-700 nm) in the water column for several depths calculated relative to the values measured in 4 m depth (100%); Station 25, on 29.06.1997 at 18°24.1N, 57°28.5 E*

5.3 Measurement and modelling of bio-optical processes (R. Reuter, R. Heuermann, W. Breves, F. Dencker)

The subproject aims at the measurement of optical parameters in the water column which allows to derive information on dissolved and suspended organic matter. Emphasis is given to the absorption and fluorescence of phytoplankton pigments, bacterial and planktonic proteins and yellow substance (chromophoric dissolved organic matter).
Combined with chlorophyll a, DOC and nutrient data measured in other sub-projects it is expected that these quantities yield data on the physiological status of plankton communities and on the flux of organic carbon between these components.
The data obtained during the cruise So120 will be used in a one-dimensional model to describe physical and biochemical processes during the south-west monsoon in the Arabian Sea. Plankton, bacteria and yellow substance are the components of the model, with meteorological forcing, vertical mixing and daylight as the parameters which determine their distribution versus depth.

The laboratory spectrophotometer (Perkin Elmer Model Lambda 18) and spectrofluorometer (Perkin Elmer Model LS50) allow an optical analysis of water samples from the rosette sampler. Absorbance spectra were taken with the photometer from 200 to 800 nm.
Samples were analysed in original form, and after filtration with 0.45 5m pore size glass fibre filters that were heated to 6000°C for three hours to eliminate organic contaminants. Purified water served as the reference medium. In this way spectra which are specific for yellow substance absorption and particle attenuation are obtained.
Fluorescence spectra were measured with: i) 420 nm excitation and 430-750 nm emission, from which water Raman scattering at 490 nm and chlorophyll fluorescence at 685 nm are derived, ii) 341 nm excitation and 360-600 nm emission, yielding water Raman scattering at 385 nm and yellow substance fluorescence in the entire emission range, with maximum values at about 420-450 nm.
Other excitation and emission spectra, e.g. in the ultraviolet for tryptophan analysis, could not be achieved because of high straylight of the excitation monochromator due to a defective optical grating. With 341 nm excitation the straylight has been suppressed by using an additional interference filter. In the laboratory later-on, fluorescence data will be corrected for the spectral sensitivity of the instrument. In a second step, a normalisation to the integral of the water Raman scatter band will be done, yielding quantitative readings denoted as “Raman units“. Data given in these units can be reproduced with any type of fluorometer.
At almost all stations water samples were taken from the rosette and analysed with the laboratory spectrophotometer and fluorometer.
The vertical profiles of yellow substance shows very low concentrations in the surface layer as a result of photobleaching effects, with increasing concentrations up to depths between 200 and 400m. In greater depths the level of yellow substance fluorescence is nearly constant. At some stations we found a local maximum of yellow substance in the chlorophyll maximum or a few meters below, which could be a result of in situ production of yellow substance.

5.4 Marine CO_2 research (R. Lendt, M. Spietz, A. Hupe)

The work performed by the CO_2 group of the IfBM during SONNE cruise 120 followed two different sampling strategies. At first 400 discrete water samples were drawn at 37 hydrographic stations and were analyzed immediately after sampling for total dissolved inorganic carbon (TCO_2) and total alkalinity (TA). The shipboard analytical methods applied are coulometric titration technique for TCO_2 and potentiometric titration for TA.

On the second hand an underway seawater pumping system supplied a newly built underway system for continuous determination of partial pressure of CO_2 (pCO_2) in surface seawater and atmosphere throughout the cruise. The system includes a *LICOR* NDIR CO_2/H_2O analyzer, similar to the Kiel system (KÖRTZINGER et al., 1996b). The pumping system supplies the pCO_2 system with a continuous flow of seawater drawn at the ship's bottom (6,5 m depth). During the cruise about 30000 one-minute datastrings for surface seawater CO_2 mole fraction (µmol/mol) and 300 for atmospheric pCO_2 were generated. The raw CO_2 mole fraction will be converted into pCO_2 (ppmv) by correcting the data with respect to the air water vapour saturation at the air-sea interface and *in situ* water temperature.

Additionally, 30 underway samples were drawn for TCO_2 and TA measurements at a transect from the coastal upwelling region to the open ocean.

The continuous determination of CO_2 mole fraction indicated constant atmospheric values of 360-362 µmol/mol. Surface waters were supersaturated nearly all the time during the cruise. Supersaturation was moderate in the open ocean (40 µmol/mol) while in the coastal upwelling region CO_2 mole fraction reached extreme high values of 800 µmol/mol. Only at a few locations near the Oman coast strong diatom blooms lowered CO_2 concentations to about 340 µmol/mol.

Fig.11 depicts the horizontal distribution of CO_2 mole fraction and sea surface temperature (SST) at an online profile from 03.07. 12:00 UTC - 04.07.97 08:00 UTC near the Oman coast. CO_2 mole fraction is closely correlated to SST and rises from 400 µmol/mol at 28.5°C to 740 µmol/mol at 21.5°C in a coastal upwelling filament. Coastal upwelling processes convey CO_2 enriched waters from 100-200 m depth to the surface, where CO_2 is degassing to the atmosphere.

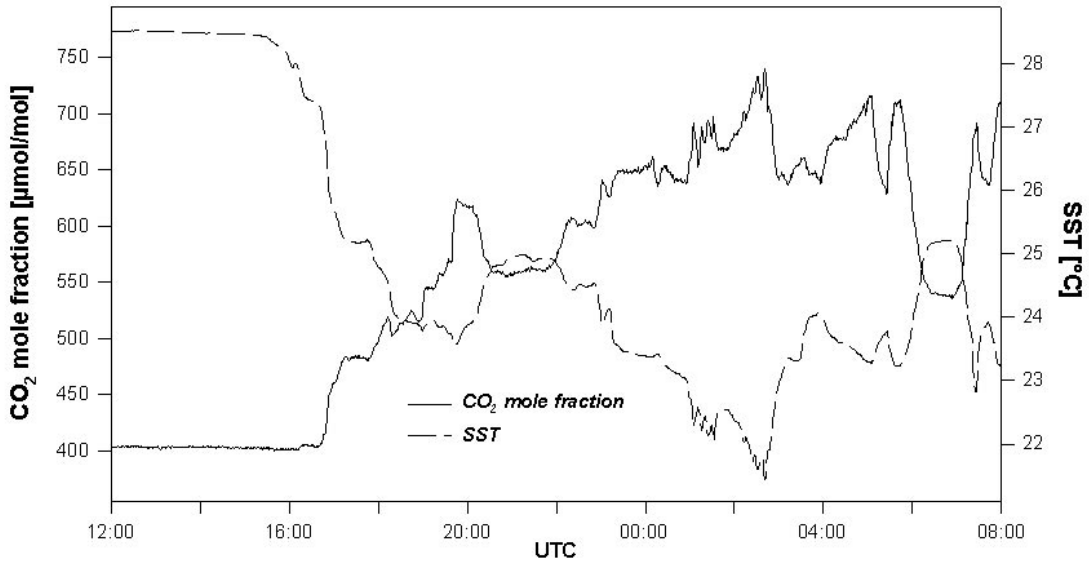


Fig. 11: *Profiles of CO_2 mole fraction and sea surface temperature between 17.53°N 59.11°E and 18.05°N 57.67°E during 03.07 and 04.07.1997 observed in one minute intervals*

Horizontal Profiles of SST, Salinity, TCO_2 , TA and CO_2 mole fraction are shown in Fig. 12 to 14. On a transect from the coastal upwelling (18.50°N 57.30°E) to open ocean regions (16.05°N 61.89°E) surface samples for TCO_2 and TA were taken from the pump system in an interval of 10 nm. SST and salinity data indicate the eastern boundary of upwelling at 59°E. They are generally increasing eastward with distance to the coast and remain constant between 59°E and 62°E (Fig 12). Therefore TCO_2 concentrations (Fig. 13) decrease from 2160 µmol/kg down to 2035 µmol/kg. CO2 mole fraction (Fig. 14) also closely correlates SST and decreases from 555 µmol/mol in the upwelling area down to 400 µmol/mol in oligotrophic waters. TA is more or less not affected by upwelling phenomena, it is rising from 2355 µeq/kg to 2400µeq/kg due to changes in salinity.

At 58.3°E low SST of 24°C and salinity 35.2 PSU and relative high TCO_2 and CO_2 mole fraction (2100 µmol/kg resp. 555 µmol/mol) clearly show an upwelling filament.

A further discussion of TC, TA and pCO_2 properties of different water masses require calibrated hydrographic data. Detailed statements about processes as remineralisation of organic matter and dissolution of calcium carbonate can be given, when all hydrographic data are completely processed.

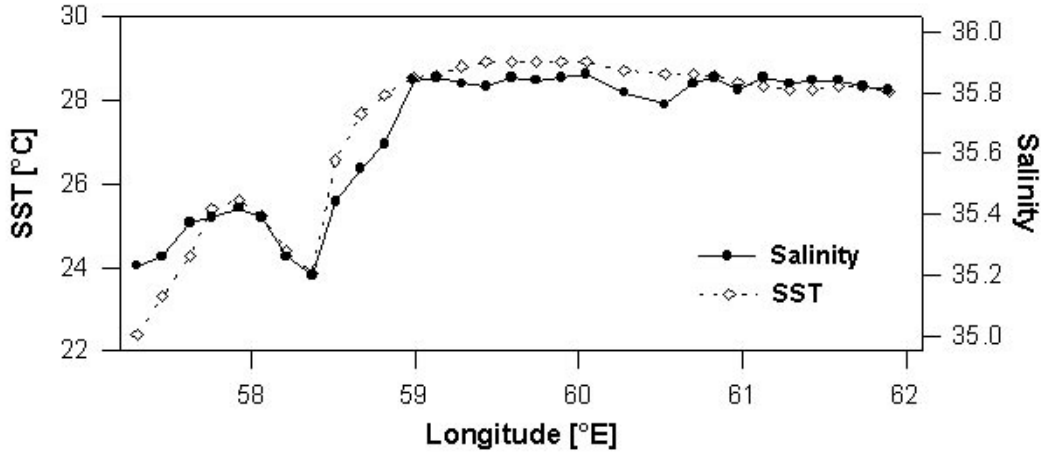


Fig. 12: *Horizontal distribution of SST and Salinity at the sea surface on a transect from 18.50°N 57.30°E to 16.05°N 61.89°E*

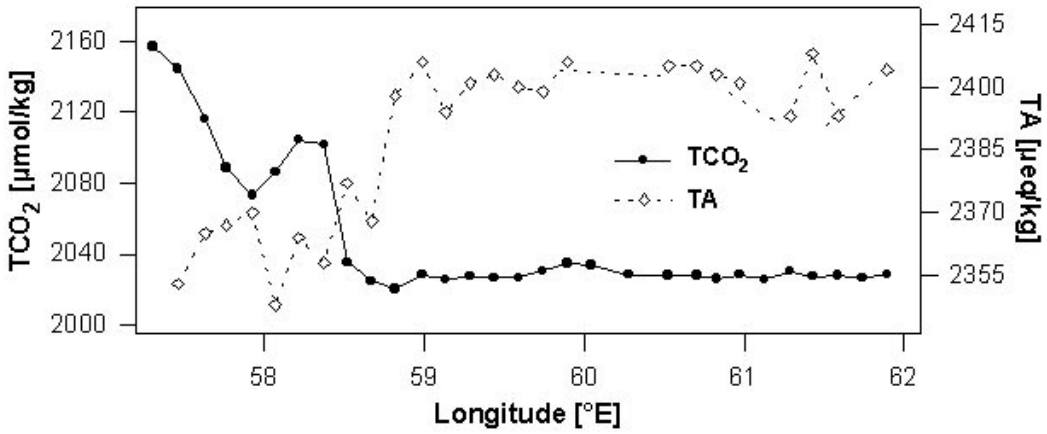


Fig. 13: *Horizontal distribution of TCO_2 and TA at the sea surface on a transect from 18.50°N 57.30°E to 16.05°N 61.89°E*

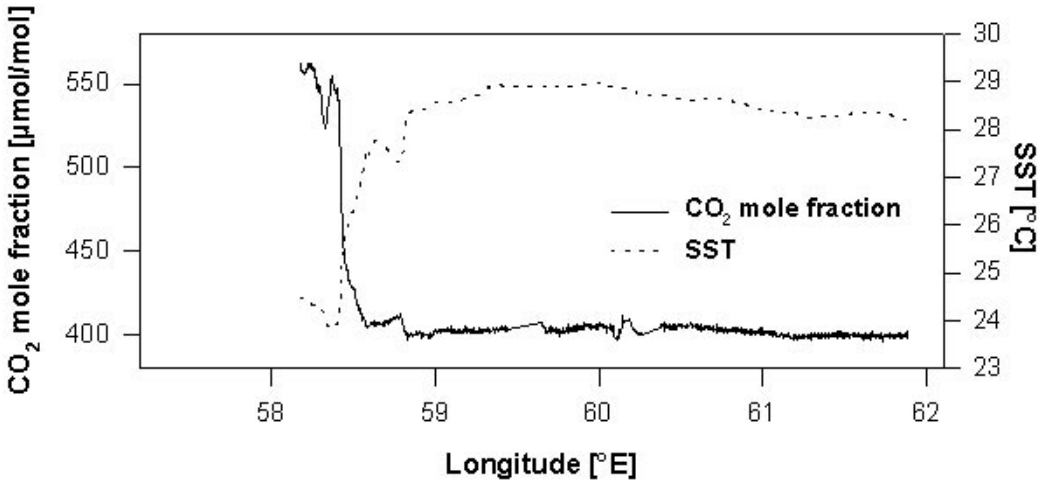


Fig. 14: *Horizontal distribution of CO_2 mole fraction and SST at the sea surface on a transect from 18.50°N 57.30°E to 16.05°N 61.89°E*

Vertical distributions of TCO_2 and SST at CTD-profiles 40, 59 and 71 are shown in Fig. 15. Mixed layer depths are varying between 20 and 50 m. Starting with low concentrations, TCO_2 profiles are marked by a strong gradient between the base of the mixed layer and about 150 m depth up to 2250 µmol/kg due to remineralization of organic matter. Further increase down to 500 m is rather slight. However, the effect of upwelling is clearly visible in the chosen profiles. Surface temperature is decreasing from profile 59 (28.5°C, open ocean) to profile 40 (22.0°C, coastal upwelling), while TCO_2 values show an inverse trend. Surface TCO_2 rises from 2030 µmol/kg in oligotrophic regions to 2190 µmol/kg in the coastal upwelling area. The source of upwelling waters can be presumed in approximately 150 m, because TCO_2 isolines in the upwelling region correspond to depths of 150 m in areas where no upwelling occurs.

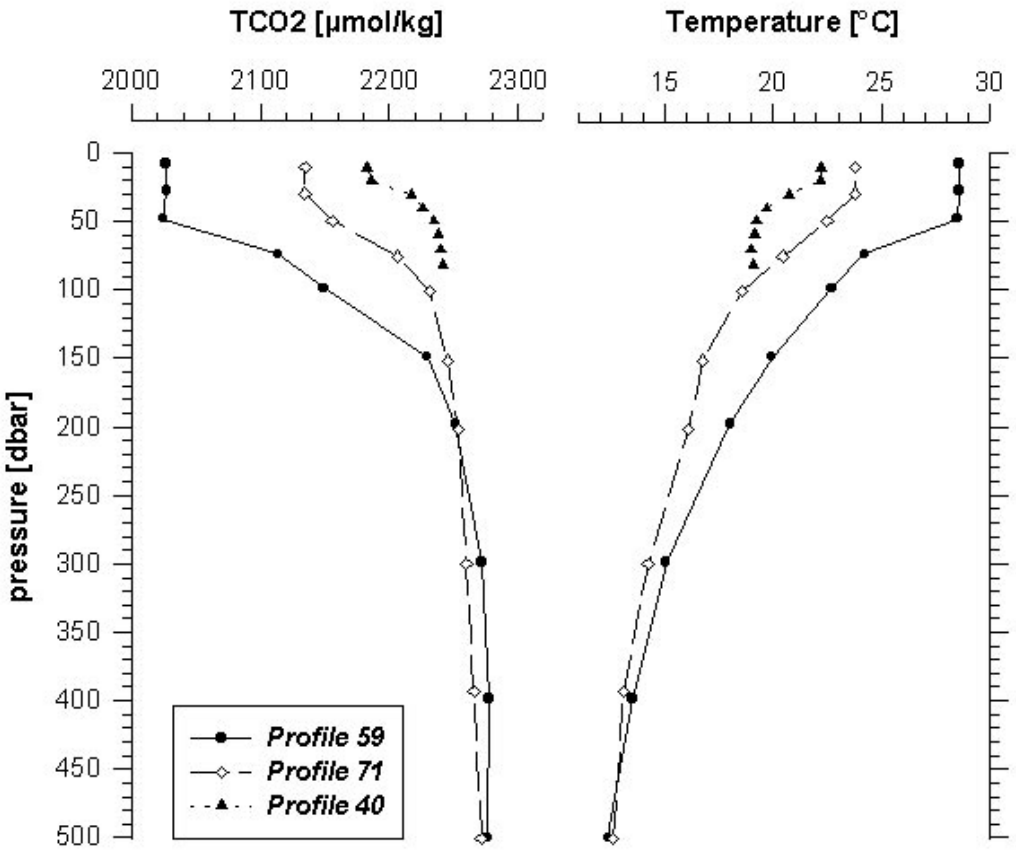


Fig. 15: *Vertical distribution of TCO_2 and water temperature in the upper 500 m at CTD profiles 40 (18.50°N 57.30°E), 59 (16.80°N 60.50°E) and 71(17.47°N 57.72°E)*

5.5 Biogenic trace gases (H. W. Bange)

The average atmospheric dry mole fractions were 311.8 ± 2.8 ppb N_2O and 1.69 ± 0.03 ppm CH_4, respectively. The average saturations in the central Arabian Sea were 106 ± 2 % for N_2O and 103 ± 2% for CH_4. Areas influenced by the SW monsoon (i.e., coastal upwelling regions) showed significantly enhanced N_2O saturations with maximum values up to 330%. N_2O saturations were closely coupled to sea surface temperatures, confirming that N_2O might be a good indicator to identify water masses influenced by upwelling processes (Fig. 16a). Maximum CH_4 saturations (up to 150%) were observed in coastal upwelling regions. However, the correlation between CH_4 saturations and sea surface temperatures was less pronounced (Fig. 16b).

At stations at the shelf and the shelf break, high subsurface N_2O concentrations (up to 55 nmol/l) were observed (Fig. 17a and 17b).The vertical distribution of dissolved N_2O in the water column of the central Arabian Sea (stations 28/57 and 34/62) showed one broad maximum at ca. 1000m water depth with concentrations up to 60 nmol/l (Figure 2b). Our results are in reasonable agreement with the distribution of N_2O and CH_4 in the Arabian Sea during the JGOFS cruises in 1995 (Bange et al., Nitrous oxide emissions from the Arabian Sea, Geophys. Res. Lett., 23, 3175-3178, 1996; Bange et al., Nitrous oxide in the central and northwestern Arabian Sea, submitted to J. Geophys. Res.- Oceans, 1997.)

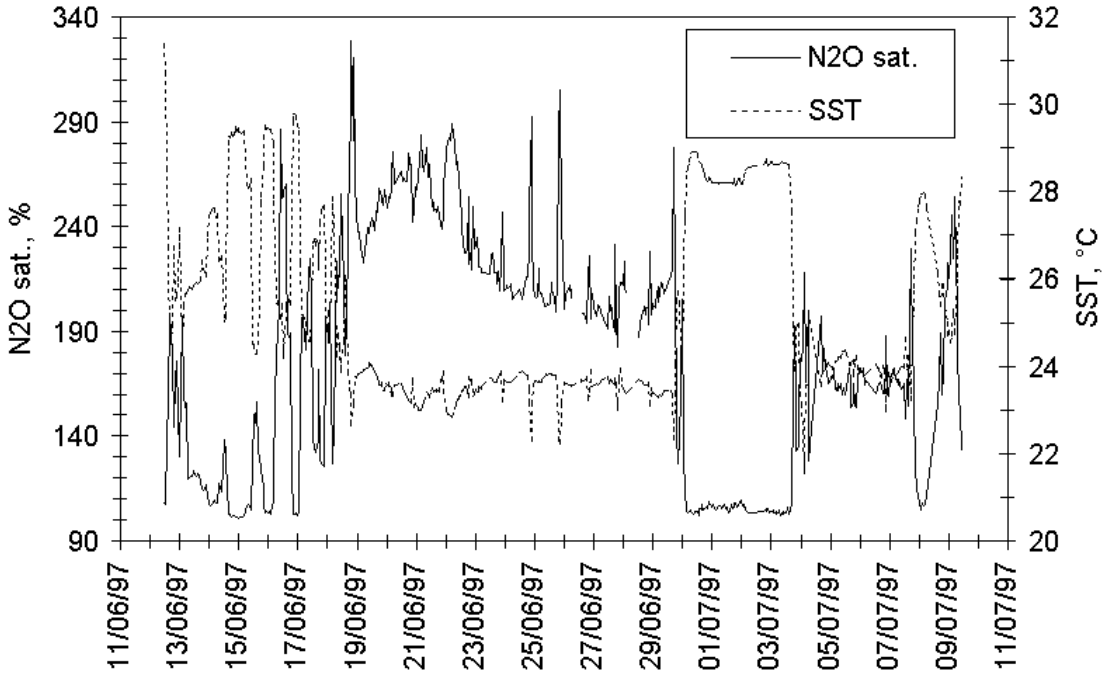


Fig. 16a: *Dissolved N2O and Sea surface temperature (SST) during JGOFS-cruise So120 (June/July 1997). The solid line represents N2O expressed as saturation (i.e., 100% = equilibrium) and the dashed line represents SST*

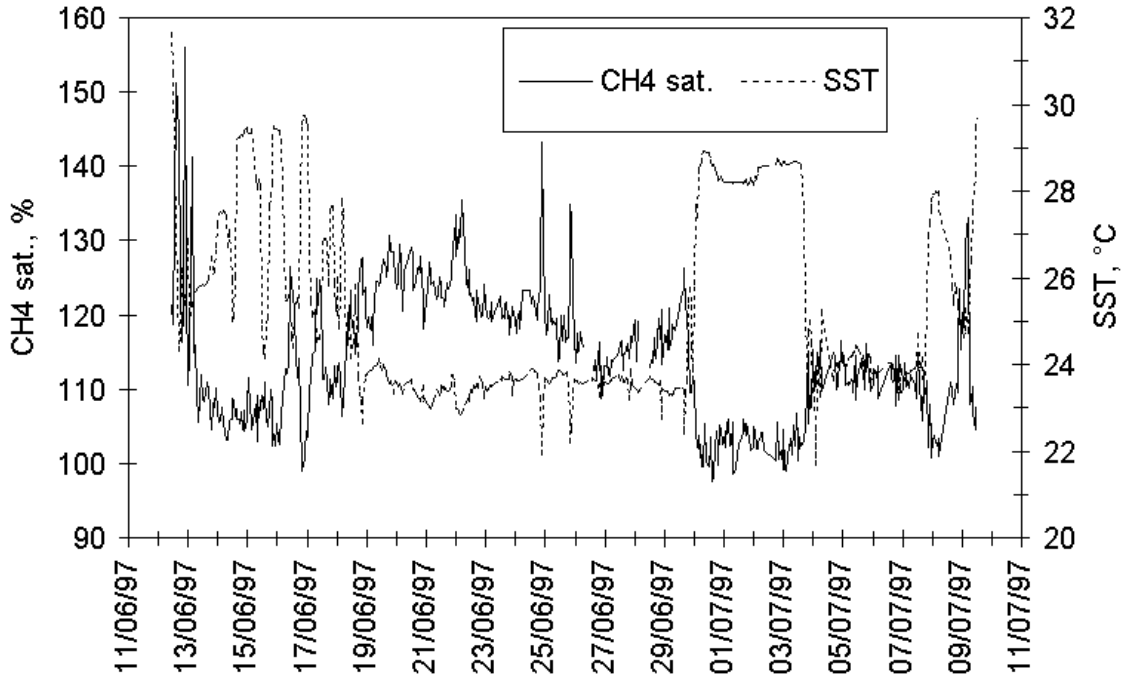


Fig. 16b: *Dissolved CH4 and Sea surface temperature (SST) during JGOFS-cruise So120 (June/July 1997). The solid line represents CH4 expressed as saturation (i.e., 100% = equilibrium) and the dashed line represents SST*

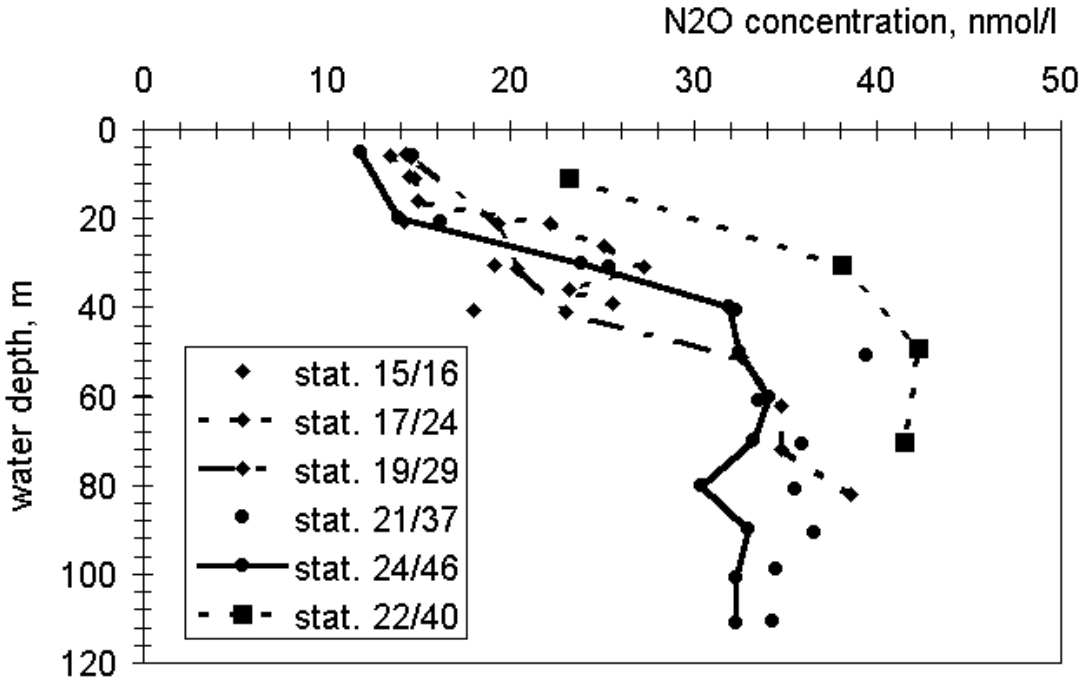


Fig. 17a: *N_2O depth profiles on stations located at the shelf of the Arabian peninsula during JGOFS-cruise So120 in June/July 1997*

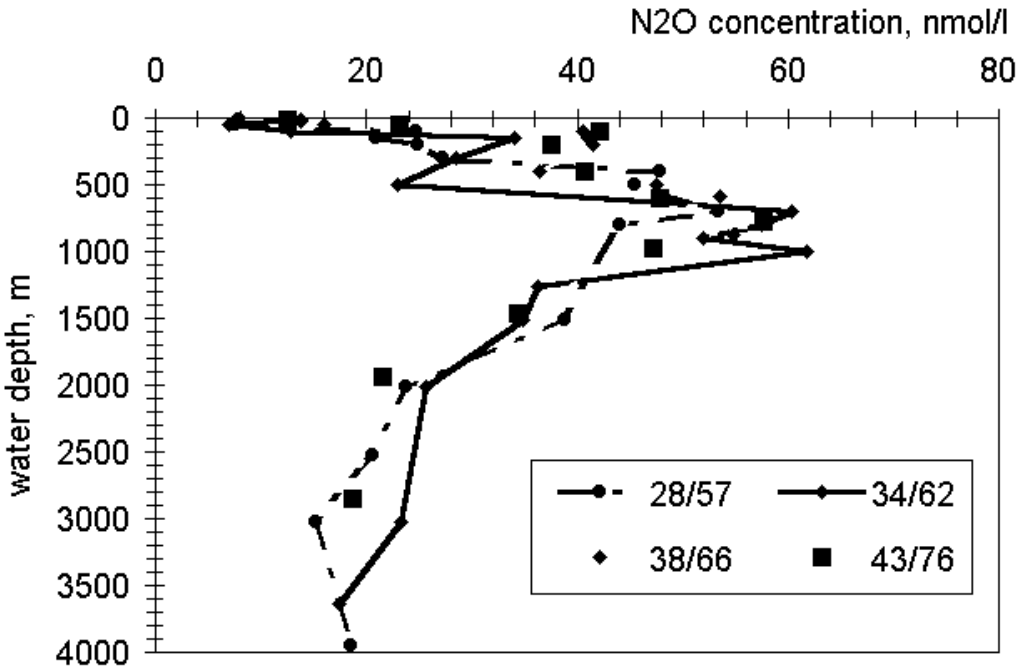


Fig. 17b: *N_2O depth profiles on stations located in the north-western Arabian Sea during JGOFS-cruise So120 in June/July 1997*

5.6 Planktological studies **(C. Sellmer, K. von Bröckel, I. Kriest, K. Nachtigall, P.Fritsche, E. Stangeew)**

The drifting array consisted of a spar-buoy with benthos spheres for flotation and an automatic Kiel sediment trap. Furthermore, the drifter was equipped with an inclinometer attached to the trap and current meters right above and below the trap to obtain informations about the movement and the position of the trap relative to the water. The positioning of the drifter was done with ARGOS transmitters as well as by visual objects (flash and banner).

The standard sampling device for all planktological samples was a combined CTD-water bottle rosette with additional sensors for oxygen and fluorescence. Water sampling for planktological bulk variables, production measurements, composition and vertical distribution of phyto- and zooplankton were concentrated into the euphotic zone, mostly within the uppermost 60 m.

For documenting the vertical particle export beyond the euphotic zone drifting sediment traps were used (see above). The trap was deployed below the euphotic zone (30-50 m). The bottom of the euphotic zone, assumed as the 1% light depth, was determined by Secchi disk measurements. Sampling periods were 12 h (sunrise to sunset and sunset to sunrise).
The elemental analysis for total particle flux, POC/PON, particulate $CaCO_3$, Chlorophyll, pigments (HPLC), and PSi and also the microscopic study for quantitative phytoplankton composition of the sediment trap material are in progress.

Furthermore, the group took care of measurements concerned with nutrient chemistry (NO_3, NO_2, SiO_4, NH_4, PO_4,), phytoplankton and zooplankton biomass and composition and planktological bulk variables (POC/N, BSI, $CaCO_3$) and other significant parts of the JGOFS core measurements (Chl *a*, HPLC, O_2).

To reveal insight into the relative importance of different phytoplankton groups some measurements for Chl *a*, *in situ* primary production and calcification rates- were carried out on different size classes.

Apstein-nets (20 µm and 55 µm mesh size) were used for direct informations about qualitative composition of the phytoplankton through microscopic analysis. Sampling took place down to about 80 m, usually 10 m below the Chl *a* - maximum.

Information about large scale horizontal distribution of nutrient and Chl *a* was obtained during transects and CTD stations every 10/30 nm (see cruise track and introduction) using a pumping system underneath the ship in 6.5 m depth.

Samples for total primary (^{14}C uptake) and new production (^{15}N uptake) measurements as well as calcification rates were taken from 5 to 6 standard depths (2, 8, 10, 15, 25, 40, and 60 m) and the chlorophyll maximum, depending on the water depth of the euphotic zone, were *in situ* incubated, attached to the drifting spar buoy, for a full light day from sunrise to sunset (12 h).

Primary production and calcification rates could be measured directly on board in a liquid scintillation counter. The ^{15}N-uptake has to be analyzed in a laboratory on land. The calcification rates measurements still need to be calibrated.

The most interesting results established from the two drifting series in the coastal upwelling region at the beginning and the end of the cruise. The eleven and four day production measurements and associated variables will be presented and discussed in detail.

The course of the drifter is presented in Fig. 2. The drifter started to move, as expected, into north easterly directions. But after ten days it turned quite abruptly back and from than on it moved more or less in a southerly direction. Average drifting speeds were between 35 and 40 cm/s (an average of 17.5 nm/d).

The first production/drifting experiment started with station number 15/15 (water depth: 54 m). The sediment trap was located in 30 m. From thereon, eleven *in situ* primary production measurements could be made each day in a row and ended with station number 25/52 (water depth: 140 m; depth of trap: 50 m). A week later the second experiment could be done with three more production measurements at the same drifting array.

Primary production started very high exceeding 3.5 g C m^{-2} d^{-1} (integrated over the euphotic zone) close to the coast of Oman. Production went rapidly down in 15 m depth (Fig. 18). Nutrient concentrations indicated a rather stratified water column with a shallow nutricline in 10 m. The concentrations were pretty high in the first 10 m and increased for NO_3, SiO_4, and PO_4 from 6.39, 0.86, and 0.81 µmol/L towards to 12.52, 6.31, and 1.38 µmol/L in 40 m respectively (Fig.19). Chl *a* - concentrations were high in the nutricline with 3.6 µg/L and went down to 0.36 µg/L in 40 m (Fig. 20).

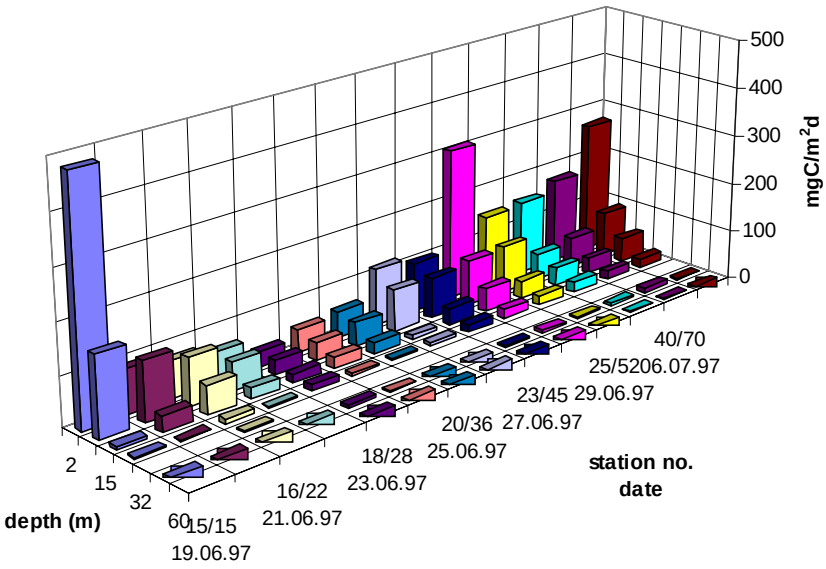


Fig.18: *Total primary production during cruise So120*

While the drifter was going on to the north-east, total primary production decreased steadily to 0.77 g C m^2 d^1 (integrated over the euphotic zone, St. 20/32, 24. June 1997). Nutrient- and Chl *a* concentrations did not show a conspicuous behavior. Primary production came up again and exceeded 2.6 g C m^{-2} d^{-1} at station 23/45 on 28. June 1997. Nutrient concentrations were increased, while Chl *a* - concentrations only went up to 1 µmol/L in the upper 25 m.

A week later, primary production started to be 1.8 g C m^{-2} d^{-1} on July 5th. The production experiment ended on July 7th with 2.6 g C m^{-2} d^{-1} (integrated over the euphotic zone).

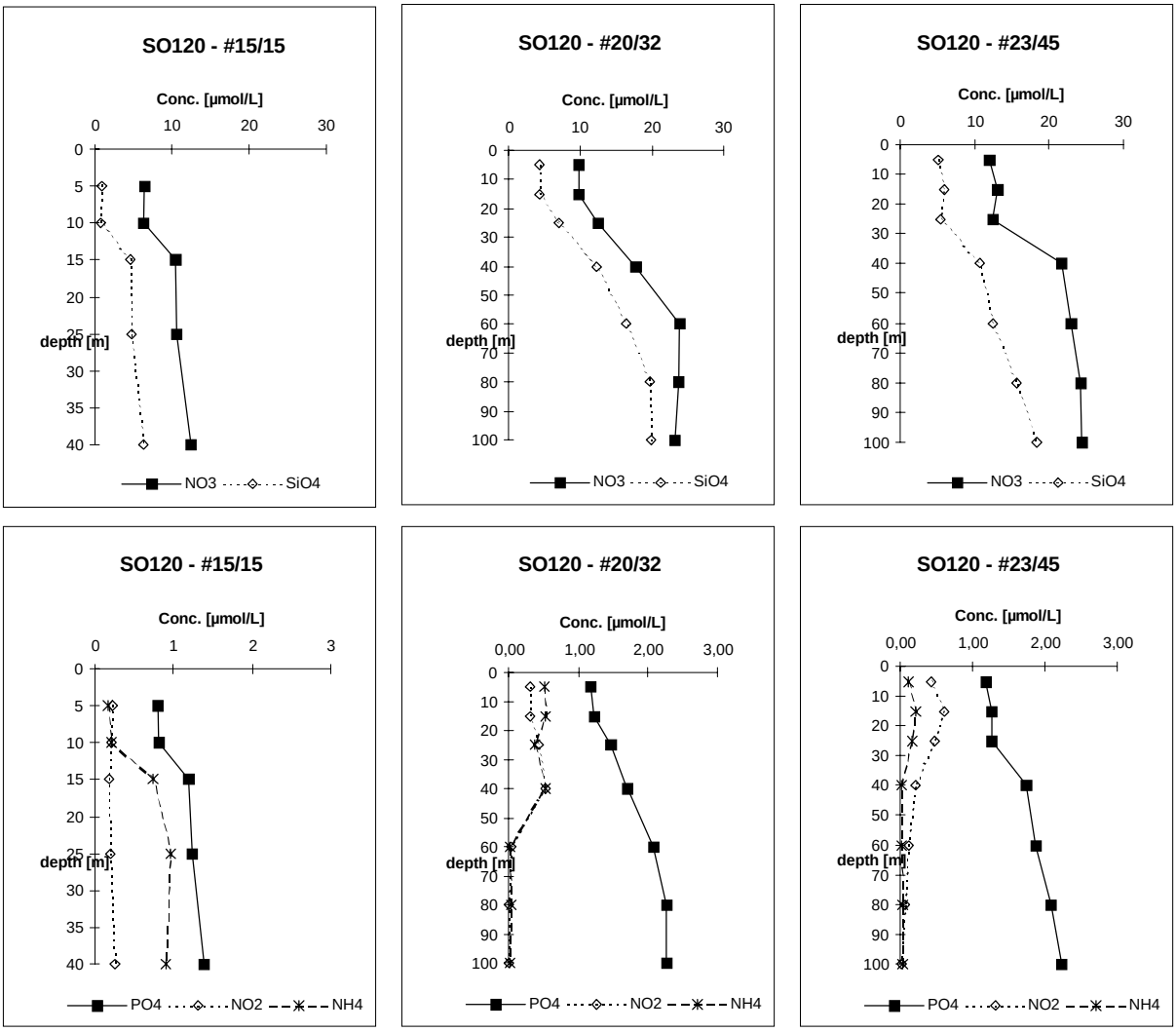


Fig.19: *Nutrient concentrations in the sampled water column form St. 15/15, St. 20/32 and St. 23/45*

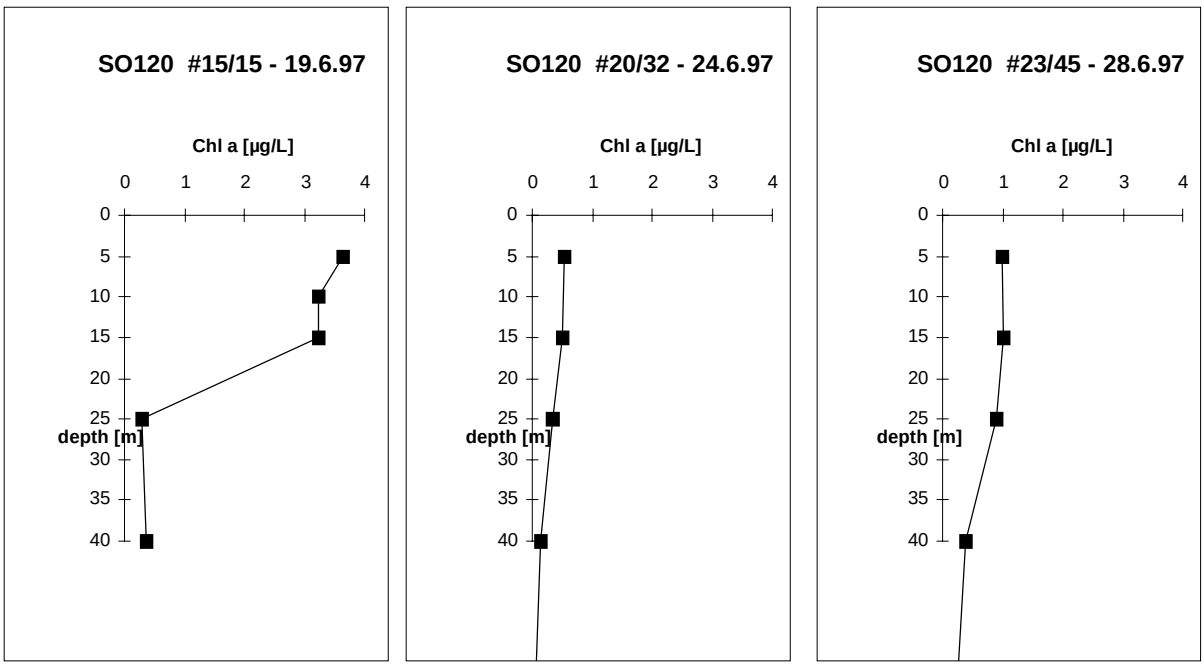


Fig. 20: *Chla concentrations for station 15/15, 20/32 and 23/45*

Primary production within different size classes of the phytoplankton population (Fig. 21) showed a very interesting picture. During this production experiment there was a shift from bigger cells (> 20 µm) at the beginning towards smaller cells (< 2 µm) at the end of the cruise. Microscopic analysis support this result. At the beginning the phytoplankton population consisted of a huge variety of different diatom species, dominated by *Thalassiosira* spp., *Nitzschia* spp., *Chaetoceros* spp., and *Rhizosolenia* spp. and others. Different flagellates as well as some small and bigger dinoflagellates were also present. In the course of this investigation pico- and nanoplankton became more and more important and explain the shift towards smaller cells, most probably dominated by the cyanobacteria *Synecchococcus* spp. (see P. Burkill).

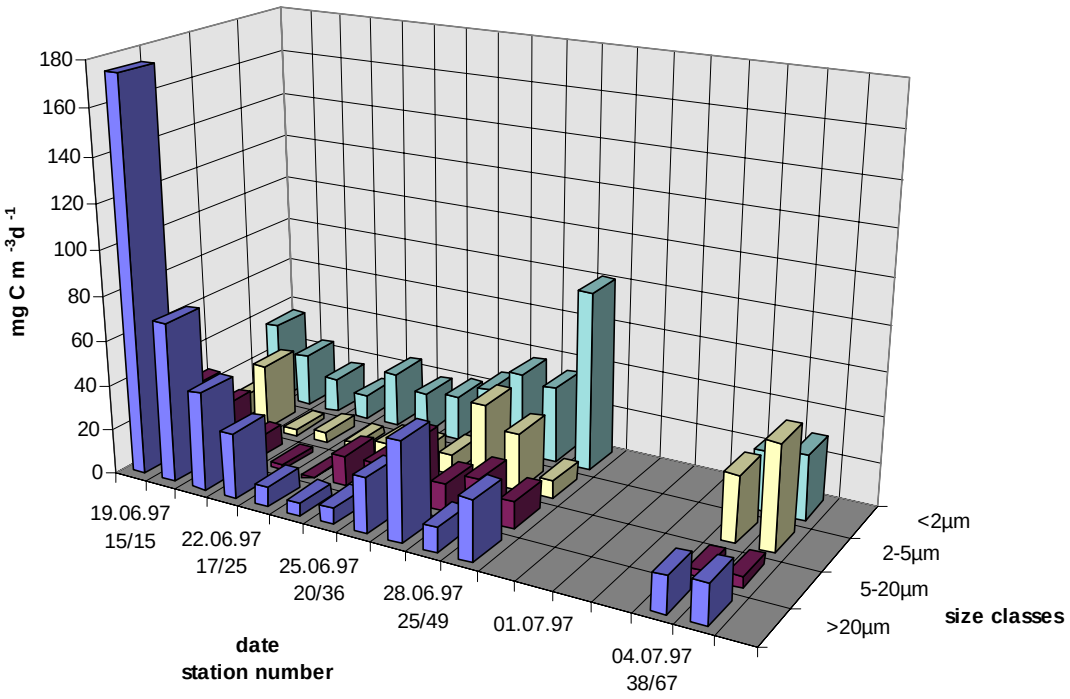


Fig 21: *Fractionated primary production during the whole drifting experiment.*

A quite similar picture emerges from the Chl *a* concentrations of different size classes of the phytoplankton population. They go conform with the fractionated primary production results (Fig. 22).

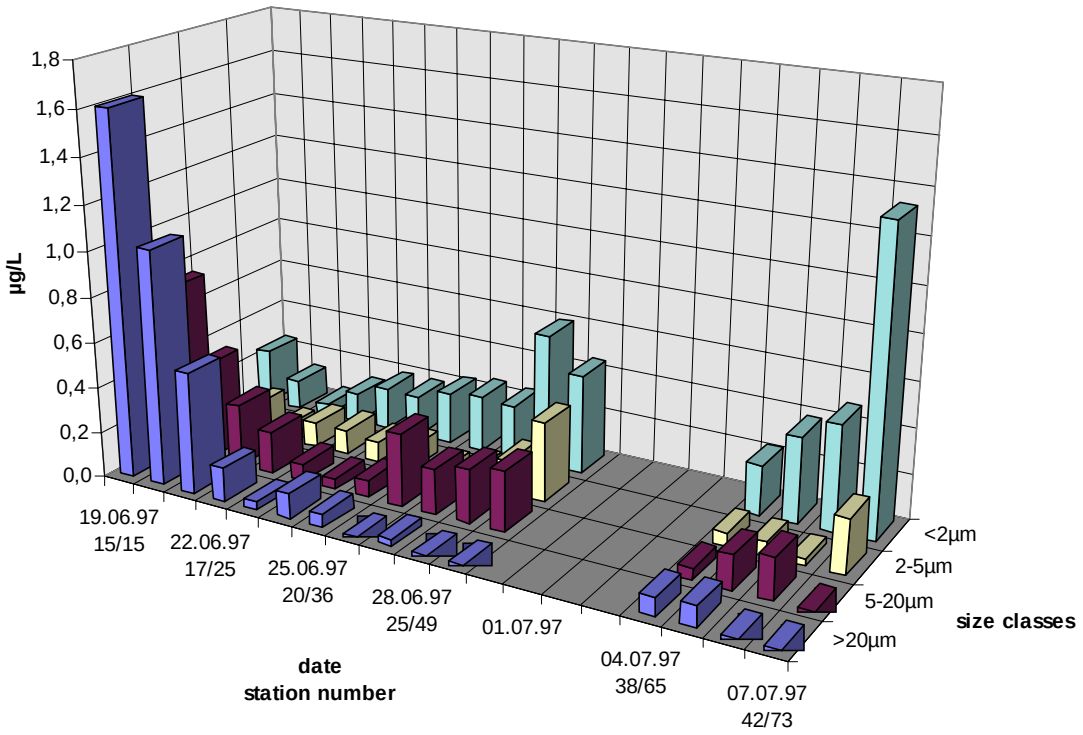


Fig. 22: *Fractionated Chl a during the whole drifting experiments*

The results obtained were not as expected. Normally, under coastal upwelling conditions with similar high nutrient concentrations to those encountered here, one would assume a proper diatom population of several or just one dominant species with a high production. This production should last until the available nutrients are more or less depleted. And only than the growth and domination of pico- and nanoplanktonic cells should occur. As mentioned above, we found quite the opposite. A solution might be found in the high abundances of micro- and macrozooplankton. A high grazing pressure existed towards medium and bigger sized phytoplankton cells. Thus, keeping those species at low abundances, although they might have had a rather big turnover rate (see part of U. Zeller).

5.7 Primary production - PxI experiments (B. Irwin)

Water samples for the experiments were collected in Nisken bottles attached to the rosette sampler of the CTD. Depths were usually 5 or 10m and the chlorophyll maximum (see Appendix A). The samples were collected from the pre-dawn station for the in situ production and at noon.

Thirty (30) aliquots of the sample were spiked with 14C sodium bicarbonate and then incubated in a light gradient incubator at *in situ* temperatures. Experiments were terminated after three hours . The phytoplankton cells were harvested on GF/F glass fibre filters and then stored for later counting. Aliquots were also filtered for Chlorophyll, POC, PON, HPLC and Absorption spectra.

Samples will be counted at BIO during september and october 1997. Preliminary results should be known by December 1997. HPLC and Absorption Spectra samples will be analysed in the fall of 1997.

5.8 Composition of autotrophic picoplankton (P. Burkill)

Samples were collected daily from CTD profiles on station (see Appendix B), and divided as follows: a) picophytoplankton (Synechococcus, Prochlorococcus and tiny eukaryotes) and nanoflagellates were analysed on board SONNE by flow cytometry; b) larger phytoplankton were fixed in Lugol's Iodine for analysis in Plymouth by Utermohl and by epifluorescence microscopy; c) bacterial samples were fixed in glutaradehyde and held frozen pending analysis in Plymouth by flow cytometry.
Subsamples were taken from dilution experiments run by Elaine Edwards and analysed on board SONNE by flow cytometry.

INSTRUMENT PERFORMANCE

1. The Becton Dickinson FACSort Flow Cytometer worked well even in Beaufort Force 9 – 10. However, instrument sensitivity was reduced throughout the cruise, resulting in poor resolution of Prochlorococcus populations from baseline noise in surface waters. Samples from depths >15m could be fully resolved. The loss of sensitivity of the photomultiplier tubes was probably caused by working in a very warm laboratory together with the possibility the instrument getting overheated in a non cooled container prior to the cruise.
2. Two analytical protocols were used succesfully for the first time to analyse a) picophytoplankton and b) nanophytoplankton. It will be interesting to compare data from the latter with Utermohl counts in due to the course.

Synechococcus populations increased consistently during Drift Station 1 from ca 10 to over 100 x 10^6 cells per litre, as shown in Fig. 23. Concentrations decreased exponentially with depth indicating that the cells were growing faster than they were mixed by vertical upwelling.

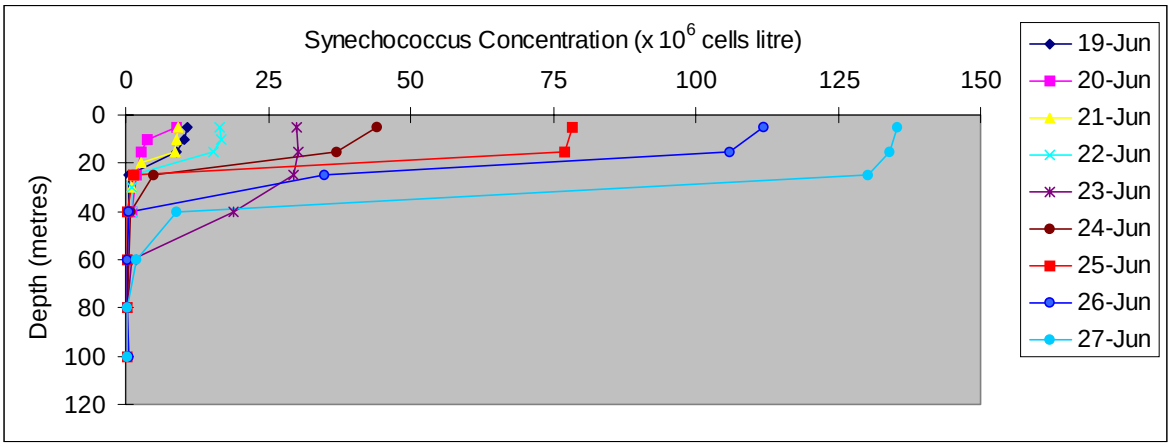


Fig. 23: *Synechococcus concentrations on Drift Station 1*

Synechococcus concentrations were lower on the second drift station indicating either a separate population or significant loss perhaps due to grazing. Concentrations in surface waters varied over the 3 days between 35 and 90 x 10^6 cells per litre (Fig. 24).

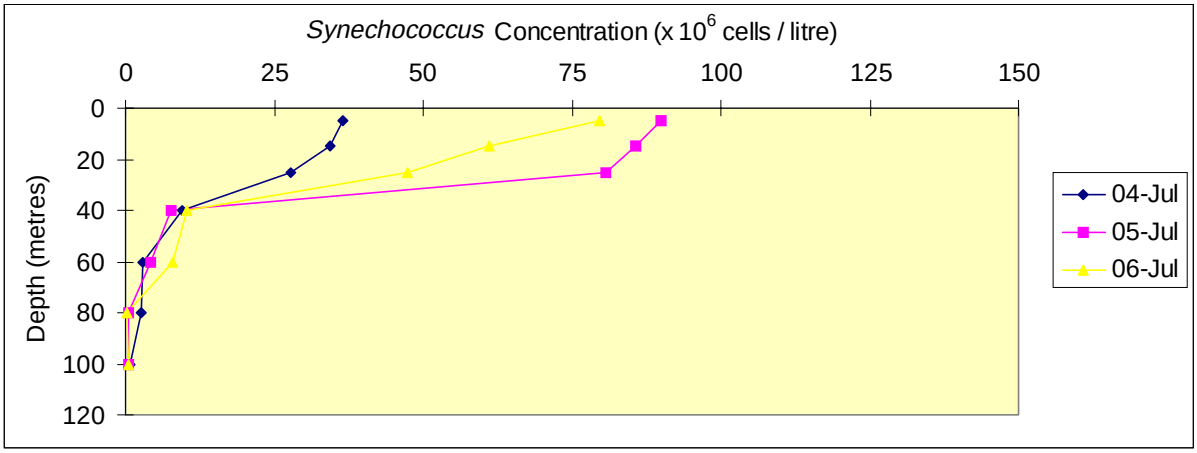


Fig. 24: *Synechococcus concentrations on Drift Station 2.*

Microzooplankton herbivory remains to be fully analysed but preliminary results (Fig. 25) show that grazing on Synechococcus was low (2% per day on 6th July).

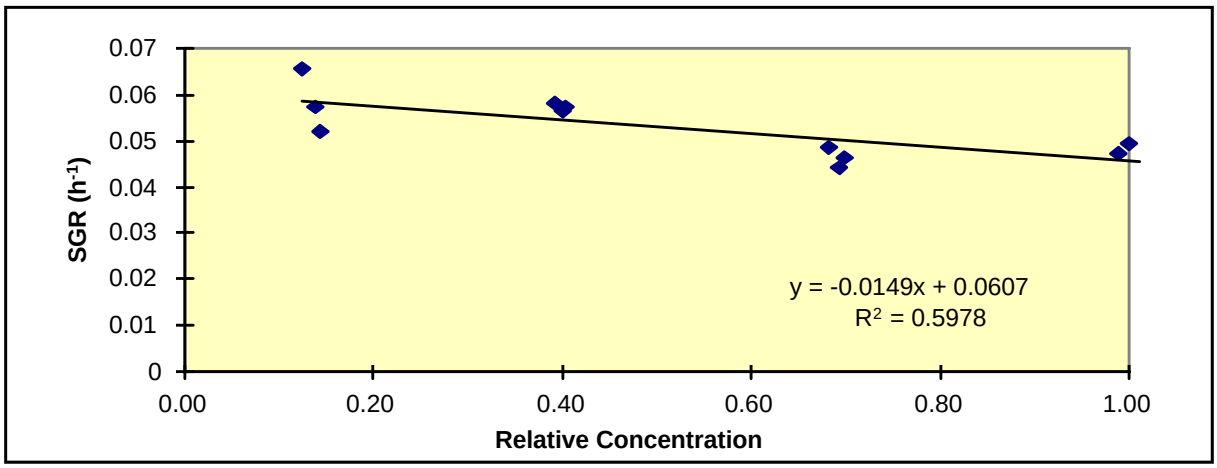


Fig. 25: *Dilution grazing plot shows low grazing by microzooplankton on Synechococcus.*

5.9 Composition of autotrophic nanoplankton (J.-J. Rick)

Cytometric measurements of autotrophic, eucaryotic plankton (size class 3 - 50 µm) were carried out on basis of water bottle samples from different standard depths (5, 10, 30, 50, 60, 70, 80, 90, 100, 120 and 150 m). For the measurements a FLUVO II cytometer designed by Dr. V. Kachel (Max-Planck-Institute for Biochemistry, Martinsried, Germany) was used. This machine was especially built to quantify the larger phytoplankton components. During the cruise the FLUVO II was a good addition to the Becton-Dickinson cytometer used by P. Burkill (see above) to determine picophytoplankton components such as cyanobacteria and prochlorophytes.

More than 700 samples from 235 depths, 37 casts, and 33 stations were analysed. The preliminary results (total phytoplankton counts per ml) are listed on the cruise CD-Rom.

The FLUVO II was also used to determine grazing rates of copepods and salps in lab experiments carried out by U. Zeller with isolated zooplankton and natural phytoplankton (see below). More than 200 samples from 8 experiments were measured.

During the two drift experiments (18.6. - 29.6., 4.7. - 6.7. 97) more than 100 plankton samples were taken in a 3 to 4 hours time sequence using an Apstein net (55 mm mesh size) and fixed using formaline. These samples will be analysed in near future using the CARPENTER method to determine brutto-growth-rates of abundant phytoplankton species. Since the phytoplankton was top down controlled during some periods of the drift experiment the knowledge about the brutto-growth of

abundant species seems to be an important information to analyse the carbon flow within the pelagic system.

5.10 Phytoplankton competition experiments and lipid composition of plankton (U. Sommer)

Shipboard competition experiments were performed in order to analyse the impact of nutrient competition on the species composition of phytoplankton. The experiments followed the design of semicontinuous cultures, with a daily replacement of 25% of the culture volume by fresh medium. The medium consisted of filtered (0.2 µm pore size) oligotrophic seawater (0.07 µM P, 0.23 µM NO_3, 0.08 µM NH_4, 1.58 µM Si) enriched by N, P, Si and trace elements in order to obtain Si:N ratios from 0.05:1 to 1.04:1 and N:P ratios of ca. 15:1. The inoculum consisted of a mixed (0-30 m depth) phytoplankton sample from station 1. A preliminary microscopic analysis of the phytoplankton assemblage sampled on day 17 from the experimental cultures showed the following patterns: The diatom *Pseudonitzschia* sp. was dominant at the highest Si:N ratio (1.04:1). At Si:N = 0.55:1 and 0.30:1 the diatom *Rhizosolenia setigera* was dominant. At Si:N = 0.18:1 the share of diatoms (mainly *Nitzschia closterium*) was <25%. Non-siliceous algae were mainly represented by the dinoflagellate *Gonyaulax* sp. (ca. 45-50%) and naked nanoflagellates (25-30%). At the lowest Si:N-ratio (0.05:1) diatoms were nearly absent, naked nanoflaggelates comprised ca. 70% and *Gonyaulax* ca. 30% of algal biomass, respecitvely. The figures are preliminary and might be corrected after reanalysis of the samples at Kiel, because of incomplete sedimentation of algae on shipboard.

Plankton from net hauls and from bottle-samples (depth of chlorophyll maximum) was size-fractionated (<64, 64-125, 125-250, 250-500, 500-1000 µm) and lyophylized for later analysis of the fatty acid composition. An aliquot of the samples was fixed by formaldehyde for later microscopic analysis. Specimen of larger zooplankton (e.g. copepodes > 2 mm, chaetognaths, salps) were picked individually for that purpose. Fatty acids will be used as taxonomic markers for the diet of metazoan zooplankton, because, contrary to algae and protozoa, multicellular animals lack the ability of a *de novo* synthesis of fatty acids. Fatty acid samples were taken at 26 stations.

5.11 Microbiology **(S. Ullrich, R. Krehl)**

Within the framework of this interdisciplinary process study microbiological investigations focused on the carbon flow channelled through bacteria into the heterotrophic food web. Especially the link between primary productivity and bacterial growth, the bacterial degradation of particles, and the grazing on bacteria by heterotrophic nanoflagellates were investigated. Although the main work was focused on high productive cold water masses near the Oman coast there was also the opportunity to

take additional samples from more oligotrophic waters and deeper layers (- 3950 m) along a transect from 15:59N 62:00E to 17:31N 59:06E.

Bacterial standing stocks (abundance and biomass) were determined using the AODC method. Bacterial secondary net production was calculated from ^{3}H - leucine and ^{3}H - thymidine uptake (JGOFS core measurement protocols). Fractionated filtration was performed to determine the portion of bacterial production which was due to particle associated bacteria on one hand and free living bacteria on the other hand.

The bulk of organic substances in aquatic environments is macromolecular and not ready for incorporation into the bacterial cell. Polymeres have to be preconditioned by extracellular enzymes to make it available for bacterial uptake. Therefore we measured bacterial extracellular enzyme activity (aminopeptidase, glucosidase, phosphatase) by use of fluorogenic model substrates in order to determine bacterial degradation of macromolecules in the water column and on particles qualitatively and quantitatively.

Grazing experiments were carried out using eucaryotic and procaryotic inhibitors to determine the portion of daily bacterial production which is consumed by higher trophical levels, especially by heterotrophic nanoflagellates (HNF) which are the most dominant bacteria grazers in the ocean.

At the beginning of the drift experiments bacterial production (calculated from ^{3}H leucine uptake) was rather high at the inshore stations. Using standard C - conversion factors (JGOFS core measurement protocols) depth - integrated (40 m) bacterial carbon production amounted to about 600 mg m^{-2} d^{-1} (Station 15). An explanation for the observed high bacterial productivity are high exudation rates by diatoms which dominated the phytoplankton community on the inshore stations. In general, a positive correlation was found between the vertical distribution of primary production, chlorophyll concentrations (determined by the planktological working group) and bacterial secondary net production (r = 0.63 - 0.99 and 0.5 - 0.99, respectively) demonstrating a clear coupling between phytoplankton productivity and bacterial growth.

Integrated values decreased with distance to the coast along the drifter trajectory (Fig. 26). Nevertheless, this decrease was not continuously and daily fluctuations were high suggesting that the drifter passed different water masses on its way.

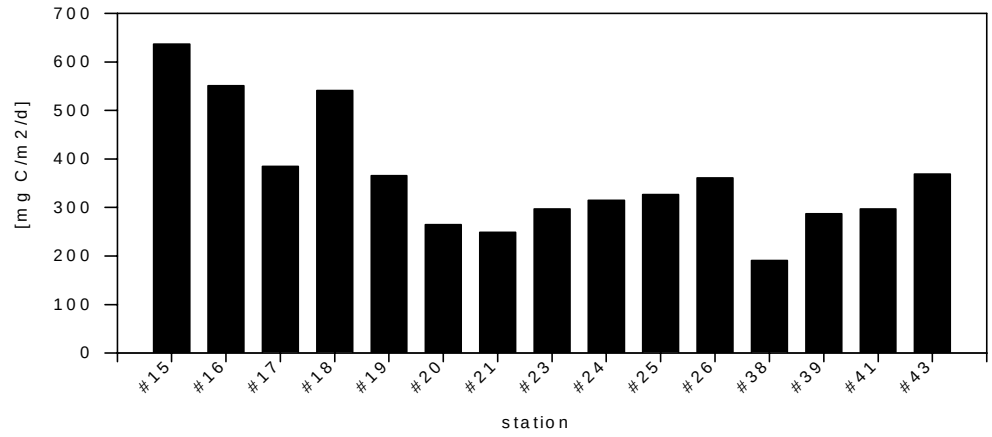


Fig.26: *Integrated bacterial production along the drift trajectory calculated from ^{3}H - leucine uptake*.

Comparable low bacterial growth rates were measured at the offshore stations (#28, #31, #34). Integrated values (whole water column) reached 130 - 280 mgC m^{-2} d^{-1}.
In general, the main part of the bacterial production (71% on average) was measured in the above 150m. This demonstrates that bacterial growth is predominantly linked to the upper layer which is characterized by high primary productivity.

5.12 Microzooplankton herbivory and community structure (E. Edwards)

Specific aims on this cruise were to a) quantify herbivorous interactions between microzooplankton and phytoplankton within the mixed layer b) collect and fix water samples in order to measure changes in the abundance and community structure of microbial populations (microzooplankton (20-200 µm), heterotrophic nanoplankton (2-20 µm) and phytoplankton) during the southwest monsoon period.

Grazing experiments

Microzooplankton grazing experiments were carried out using the dilution technique described by Landry & Hassett in 1982 (*Mar Biol* 67: 283-288). This method has been developed and used successfully during previous projects (e.g. BOFS, ARABESQUE, OMEX).

Experimental water was collected pre-dawn from the surface mixed layer using 30 litre Go-flo bottles. Half of this water was filtered through a 0.2 µm Gelman Supor-capsule filter which had been pre-rinsed in deionised water. The remaining water was pre-screened using a 200 µm mesh bag. A series of dilutions were made up by gently combining the screened water with the filtered water in 2 litre polycarbonate bottles. Sub-samples were taken at Time (T_0) from each dilution bottle for (I)

measurement of chlorophyll (ii) flow cytometric analysis by P. Burkill (sea above) and (iii) for the determination of community structure. Each bottle was then gently topped up to remove any air and placed into the deck incubator. All incubations were run for approx. 24 hours (with exception of one on 7/7 which lasted 12 hrs). Ambient light levels were matched using a 33% or 55% light screen. At the end of the incubation period, further sub-samples were taken for chlorophyll and flow cytometric analysis and fixed in Lugol's for community structure determination. All chlorophyll samples were extracted with 90% acetone and analysed on board by fluorometry. All community structure samples will be analysed on return to the laboratory.

Details of each grazing experiments carried out are shown in Tab. 3 .

Tab. 3: *Microzooplankton Grazing experiments*

Date	Station	Depth
19/6	15	10m
20/6	15	10m
21/6	16	15m
22/6	17	10m
23/6	18	15m
24/6	20	10m
25/6	20	10m
26/6	23	10m
27/6	23	10m
28/6	25	10m
29/6	25	10m
5/7	38	11m
6/7	40	7m
7/7	42	10m

Water Sample Collection

Water samples were collected at 5-8 depths from 10 litre water bottles on the CTD and were fixed as follows:

Microzooplankton: 500 mls in 1% acid Lugol's for the subsequent determination of total microzooplankton biomass and species composition. The above samples will be analysed at PML using inverted microscopy and image analysis.

Heterotrophic Nanoplankton: 25-50 mls in 0.3% glutaraldehyde, dual-stained with DAPI and proflavine (final concentration 5 mg ml^{-1}) and filtered onto 0.8 µm black polycarbonate filters. The filters were mounted onto slides and frozen until subsequent analysis at PML by inverted fluorescence microscopy.

Phytoplankton: 150 mls of water sample was fixed in (I) Lugol's and (ii) formalin. These samples will be analysed by Derek Harbour at the PML for information on phytoplankton species composition and biomass.

5.13 Calcareous and siliceous particle flux during the southwest-monsoon (A. Zeltner)

The spatial and temporal distribution and the particle flux of the calcareous and siliceous micro- and mesofauna (planktic foraminifers, pteropods, radiolaria) and micro- and nanoflora (coccolithophores and diatoms) is investigated. First studies were carried out during Meteor cruises M 31/3 (March, 1995), M 32/3 (May, 1995), M 32/5 (July and August, 1995), and M 33/1 (October, 1995). Further sampling has been carried out during the RV Sonne cruises 117, 118, 119, and 120, from April through July, 1997. The data serve for seasonal (monsoon) and interannual comparison of the fauna / flora and calcite flux. This will improve interpretation of fossil asssemblages for reconstructing the Quaternary evolution of the monsoonal system.

Sampling strategie

During RV Sonne cruise 120 sampling was carried out with a multiple opening-closing net (100 µm) with integrated water samplers (5 liters). In total, 24 net hauls were employed. The upper 100 m were sampled at 20 m depth intervals. In shallower water depths, intervals ranged between 5 and 10 m. Water samples were taken synchronously, mostly at 100 m, 60 m, and 20 m depth. Below 100 m intervals ranged between 100-200-300-500-700, and 1000 m depth. Water samples were taken at 200, 300, 500, 700, and 1000 m depth.

Water samples were filtered through a 0.45 µm screen using a vacuum pump (200 mbar), to investigate coccolithophores / coccoliths, diatoms, radiolaria, and smaller foraminifera. On average 5 liters of water were filtered. The samples will be analysed by SEM in our laboratory in Tübingen. For stable isotope investigation, 50 ml water samples were fixed with $HgCl_2$.
During filament survey (Station 3-13, 17° 17’ 45,8’’N/ 56° 02’ 58,4’’E - 18° 13’ 29,6’’N/ 57° 35’ 46,1’’E) net hauls were carried out to a depth of 100 m. A large number of empty planktic foraminiferal tests of small size fractions (Station 3-9), was followed by a decrease of planktic foraminifers at stations 11 and 13. *Globigerinella siphonifera* and *Orbulina universa* were most evenly distributed with water depth. Specimens of *Globigerinoides ruber* (white), *Globorotalia menardii*, *Neogloboquadrina dutertrei* were recorded from the upper 100 m depth. *Limacina inflata* and *Limacina trochiformis* (pteropods), showed a quantitaitve decrease during the survey.

During the drifter-experiment only a very scarce number of planktic foraminifers occurred in depths above 100 m. In net-hauls up to 100 m and water depths below 100 m *N. dutertrei*, *O. universa*, and

Globigerina bulloides have been recorded. Also pteropods, *Limacina* spp., *Creseis* spp., and *Diacria* spp., occured in very low numbers.

Continuing the drifter experiment (03.07.-07.07.1997) in deeper waters many small planktic foraminifers were recorded. Species composition was the same as recorded from shallower waters.

Generally, the diversity of planktic foraminifers was low, but planktic foraminifers always occurred in higher numbers than pteropods.

5.14 Zooplankton (U. Zeller)

The aim of the mesozooplankton study during this cruise was to elucidate the role of mesozooplankton in the ocean carbon cycle. For that reason mesozooplankton samples were taken with a multi open and closed net (mesh size 200 µm) on 15 stations at the drift stations.
Mesozooplankton sampling were carried out in vertical hauls at four depth intervals of 100 m and/or 20 m by respectively water depth of 500 and/or 80 m. For each haul the samples were divided into equal portions using a Folsom plankton splitter. One aliquot was fixed with formaldehyde for later determination of species composition and abundance. The second aliquot was divided into different size fractions (> 1000 µm, 1000-500 µm, 500-300 µm, 300-200 µm and < 200 µm) for analyses of particulate organic carbon and particulate organic nitrogen.

The first overlook on mesozooplankton composition shows a tropical assemblage with high diversity of different taxonomic subgroups (e.g. Copepods, Ostracods, Amphipods, Euphausiids, Medusae, Siphonophores, Appendicularia, Salps, Radiolaria, Foraminifera and Ciliates). The higher abundances were in the fraction larger than 500 µm. Near the coast a high abundance of calanoid copepod species *Calanoides carinatus*, a genus indicating upwelling situations. Furthermore, a huge variety of mesozooplankton population could be observe between the stations. This variety (patchiness) may result from physical turbulence or mixing as well as interactions between zooplankton and their food (see Planktological Studies). Analysis of biomass (dry weight) and of carbon/nitrogen compounds of the material still in progress.
Additionally grazing experiments were performed with *Calanoides carinatus*, *Eucalanus* spp. and with salps. The animals were sorted out from a Ringnet hol (1 m² area of opening and mesh size of 200 µm). This net allows to catch mesozooplankton due to the closed cod end without stress, which is important by experiments. At all experiments the animals were fed with natural phytoplankton out of the Chl *a* - maximum depth (10-15 m). At each experiment a number of 10 to 15 animals were incubated in a 1 litre bottle with natural phytoplankton. A total of 4 bottle were incubated to get an idea of the deviation between the animals. The bottles were incubated over 10 to 13 hours in a dark rolling tank cooled with surface water (temperature of 28 °C) over the whole incubation time. At each experiment 2

control flasks with only natural phytoplankton were incubated for determination of possible changing Chl *a* concentration during incubation time due to microzooplankton grazing.

The experiments carried out with *Calanoides carinatus* show a very slow decrease in Chlorophyll a concentration (Fig. 27). The grazing rates of *C. carinatus* were between 0,5 and 0.8 ng Chl *a*/animal/hour. Contrariety are the results from grazing experiments carried out with *Eucalanus* spp (Fig 28), with grazing rates of 5 ng Chl *a*/animal/hour. Although both animals belong to the group of planktonic crustaceans, calanoid copepods and their feeding mechanics are similar they show different grazing rates. This result supports the hypothesis that the phytoplankton stock dominated by small cells (< 2 µm) at the station where the experiment was run with *C. carinatus* was underexploited whereas in the grazing experiment with the *Eucalanus* spp. the phytoplankton stock was dominated by larg cells (> 20 µm) and not underexploited. The higher grazing rates between 3.0 and 13 ng Chl *a*/animal/hour were measured by the experiment carried out with salps (Fig. 29). The high variability in grazing rates was due to some animals not feeding during the experiment.

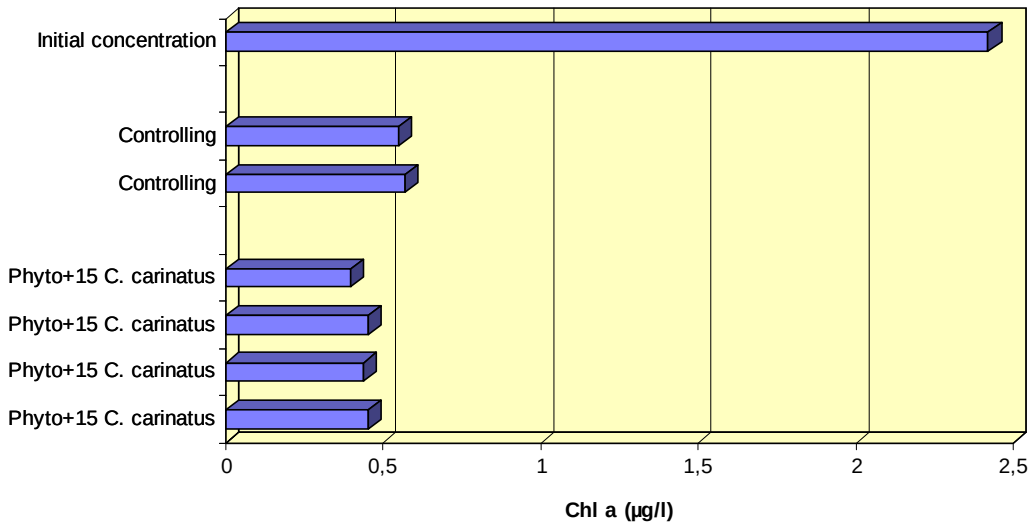


Fig. 27: *Grazing experiment carried out with Calanoides carinatus*

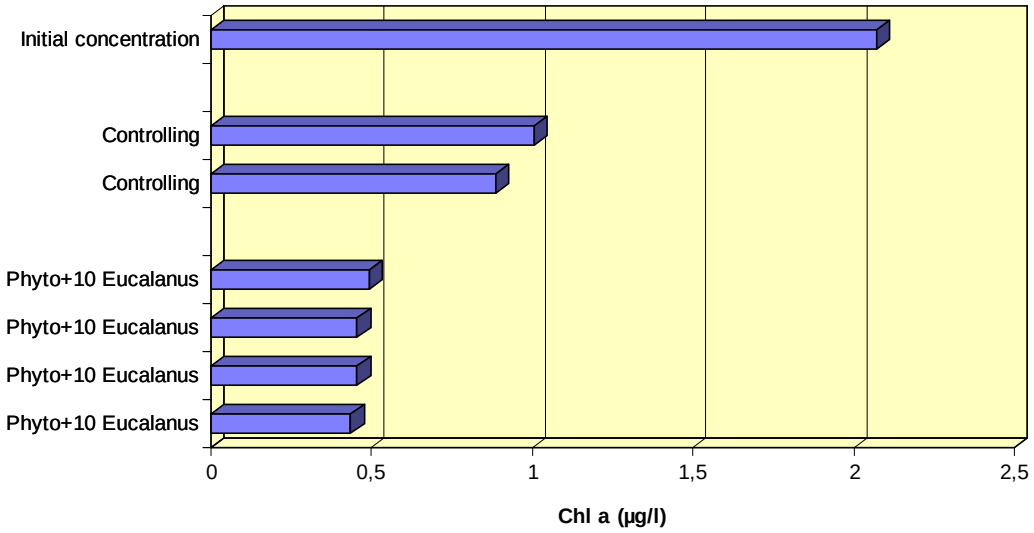


Fig. 28: *Grazing experiment carried out with Eucalanus spec.*

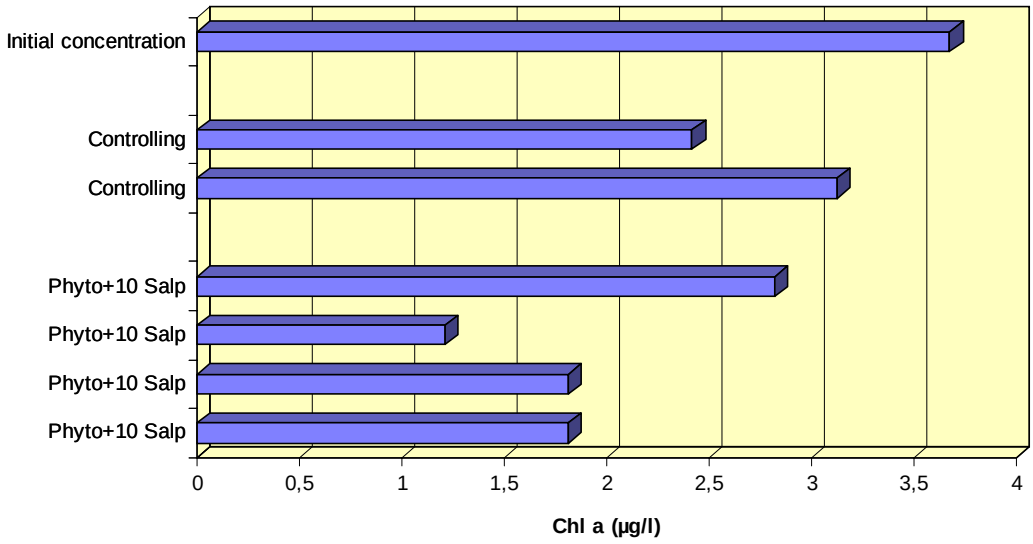


Fig. 29: *Grazing experiment carried out with salps*

This results indicate that in the upwelling region at the coast of Oman mesozooplankton plays an important role through their high biomass and grazing pressure towards medium and bigger sized phytoplankton cells. Additional indications of their intense grazing pressure on phytoplankton were high amounts of faecal pellets in the nett samples, which on the other hand will contribute to the POC flux out ot the euphotic zone into the particle trap.

5.15 Radionuclides as tracers for particle modification in the Arabian Sea (S. Becker, J. Scholten)

Processes which control the transport of ocean ingredients from the water column to the ocean floor sediments are among the key issues in understanding the oceans´ chemical budget. Natural radionuclides, e. g. 234Th, 232Th, 230Th, 231Pa, 210Po, and 210Pb, have been found to be useful tracers to study the geochemical pathways of particle reactive material in ocean waters. The source and the production rate of these radionuclides is well known; due to their particle reactivity they quickly adsorb on particle surfaces and are removed from the water column. Within the frame of the German JOINT GLOBAL FLUX STUDIES (JGOFS) the distribution of natural radionuclides in the water column, in sediment traps and in surface sediments is determined. The objectives of these investigations are:

- to determine the trapping efficiencies of sediment traps deployed in the Arabian Sea
- to investigated the effects of boundary scavenging on the distribution and fluxes of oceanic material
- to determine particle exchange rates (Adsorption, Desorption; Aggregation, Disaggregation) in the water column and their differences between monsoon and intermonsoon periods
- the influence of the oxygen minimum zone on particle exchange rates
- the influence of lateral sediment transport near the ocean floor (benthic nephloid layers) on the particle flux into the sediments.

In order to investigate the effects of the south west monsoon on particle dynamics, the water column was sampled during the SONNE cruise 120 on three stations (stations 28, 31, 34) covering a transect from the Oman margin to the sediment trap location WAST. At these stations the water column was sampled in 6 depth levels with 40l of water each. For measurements of 230^{Th} and 231Pa, two 10l pre-cleaned jerricans were filled. Further purification of these samples and masspectrometer measurements will be performed in the home labs. For the determination of particulate and dissolved 210Po, 210Pb and 234Th (particulate), 20l of water were filtered on board using Nucleopore filters (1 µm). The filters were folded and stored in plastic dishes for further analyses in the home lab. The filtrate was spiked, acified and Fe-chlorid was added. After about 24 hours (to allow for chemical equilibration) Fe was precipitated by adding NH3. Further chemical purification of the samples will be performed in the home labs.

5.16 Data management (Thomas Mitzka)

Participation on the surway was an exelent exercise for project related data management. In narrow cooperation with the scientists a cruise data CD-ROM was planned and processed on board. Every principal investigator took his copy of the first version of the available cruise data on CD-ROM home. This data product, the scientists agreed, is a very useful tool to get an integrated overview and to compare and support the own results with other parameter. The common work of scientists and data manager on a research cruise over longer period of time led to a deeper understanding of each others work.

The creation of the CD-ROM was prepared in five steps.
The first step, the preliminary work done by the data manager, was the creation of concept. This concept includes a detailed description of the CD-ROM structure and the organization of the different data types. A statement on data politics (Appendix C), every scientist had to agree with to guarantee data security, was planned in detail. Instructions on data documentation, a short completion form (Appendix D) for the scientists to fill out, was created. Last not least the station inventory, including all information about place, time, station numbering and more, was constructed. On the other hand first arrangements were made with the system operators of the vessel, to check their technical equipment and to discuss the best way to transfer the data from a PC onto a CD-ROM.

The second step was the discussion of the draft with the scientists. The most controverse discussed item was the structure of the CD-ROM, but at the end a good compromise was found to satisfy all needs (Appendix E). The different philosophies in storing and organising data and the varying points of view of the CD- ROM's data contense gave a good overview of the scientists needs on such a data product. These partly new pieces of knowledge of the users claims on data products are very useful for the future work on creation of consistent data sets and their distribution on disk or CD-ROM.

The third step was the data collection and the reformatting to create a consistent data format and to avoid the storing of redundant and useless information. The basis of this procedure was to get a data set from the originator with all available information to start a first quality check and to mark data with problems. If incorrect data points were found, the scientists checked it and gave the up-date back. Problem are liable to occur in the part of meta information (place, time, depth, etc.) because of wrong protocolling or of corrections on these data performed at a later date. At the end of the cruise a preliminary data set of 65 megabytes was collected.

With the end of compilation of the different data sets and the scientists comments, the fourth step of the CD-ROM creation started the final discussion. It is necessary to include the data originator in nearly every step of the project. Because making the work of data managing transparent and showing the great advantages of data products helps to shorten the time of data delivery to the data base. The final discussion was very short, because most of the scientists ideas and comments were discussed in past and included into the CD-ROM concept.

The fifth and last step was the preparation of the CD- ROM's. We used the ships intranet to transfer the complete data set from the data managers PC onto the system operaters workstation. This procedure took only a few seconds and was performed successful. The creation of one CD-ROM took about 45 minutes depending more on the writing velocity than on the amount of data which had to be written on the ROM. This has a very time consuming part of the project and every data logger had to be tested after creation. Making CD-ROM's during a cruise could be a kind of „rolette", because due to ship movements the CD's can get damage and a lost of up to 30% can occure. On this cruise furthermore we had no loss of any CD's.

Appendices

Appendix A: **Samples taken for P.I. experiments (B. Irwin)**

ID	DEPTH	LAT	LONG	STATION	DATE	START	END
170201	10	16 45	55 50	2	15/6/97	602	902
170202	60	16 45	55 50	2	15/6/97	622	922
170203	10	17 17	56 03	3	15/6/97	1230	1530
170204	40	17 17	56 03	3	15/6/97	1241	1541
170205	10	17 46	56 14	4	15/6/97	1815	2015
170206	10	17 35	56 46	7	16/6/97	1040	1340
170207	40	17 35	56 46	7	16/6/97	1053	1353
170208	5	18 08	56 43	8	16/6/97	1810	2010
170209	10	18 08	56 43	8	16/6/97	1628	1920
170210	10	17 57	57 23	11	17/6/97	845	1150
170211	30	17 57	57 23	11	17/6/97	845	1150
170212	10	18 29	57 12	12	17/6/97	1350	1650
170213	20	18 29	57 12	12	17/6/97	1405	1705
170214	5	17 50	56 51	15	19/6/97	540	840
170215	10	17 50	56 51	15	19/6/97	555	855
170216	5	17 50	56 51	15	19/6/97	1107	1407
170217	10	17 50	56 51	15	19/6/97	1120	1420
170218	20	17 50	56 51	15	19/6/97	HPLC	
170219	30	17 50	56 51	15	19/6/97	HPLC	
170220	40	17 50	56 51	15	19/6/97	HPLC	
170221	5	17 51	56 51	16	20/6/97	535	835
170222	10	17 51	56 51	16	20/6/97	548	848
170223	5	17 52	56 54	16	20/6/97	1350	1650
170224	10	17 52	56 54	16	20/6/97	1405	1705
170225	20	17 52	56 54	16	20/6/97	HPLC	
170226	30	17 52	56 54	16	20/6/97	HPLC	
170227	5	17 53	56 55	17	21/6/97	528	828
170228	15	17 53	56 55	17	21/6/97	541	841
170229	10	17 53	56 55	17	21/6/97	1400	1653
170230	20	17 53	56 55	17	21/6/97	1412	1712
170231	30	17 53	56 55	17	21/6/97	HPLC	
170232	40	17 53	56 55	17	21/6/97	HPLC	
170233	5	17 53	56 57	18	22/6/97	523	823
170234	10	17 53	56 57	18	22/6/97	538	838
170235	10	17 55	57 02	18	22/6/97	1400	1650
170236	20	17 55	57 02	18	22/6/97	1415	1715
170237	30	17 55	57 02	18	22/6/97	HPLC	
170238	40	17 55	57 02	18	22/6/97	HPLC	
170239	60	17 55	57 02	18	22/6/97	HPLC	
170240	15	17 55	57 05	19	23/6/97	520	820
170241	40	17 55	57 05	19	23/6/97	542	842

170242	10	17 57	57 09	19	23/6/97	1400	1645
170243	20	17 57	57 09	19	23/6/97	1413	1713
170244	30	17 57	57 09	19	23/6/97	HPLC	
170245	40	17 57	57 09	19	23/6/97	HPLC	
170246	60	17 57	57 09	19	23/6/97	HPLC	
170247	5	17 57	57 12	20	24/6/97	519	819
170248	15	17 57	57 12	20	24/6/97	535	835
170249	10	17 59	57 14	20	24/6/97	1357	1648
170250	20	17 59	57 14	20	24/6/97	1410	1710
170251	5	18 03	57 15	21	25/6/97	515	815
170252	15	18 03	57 15	21	25/6/97	532	832
170253	10	18 06	57 16	21	25/6/97	1352	1644
170254	20	18 06	57 16	21	25/6/97	1405	1705
170255	5	18 11	57 19	23	26/6/97	518	818
170256	15	18 11	57 19	23	26/6/97	533	833
170257	10	18 12	57 19	23	26/6/97	1345	1630
170258	20	18 12	57 19	23	26/6/97	1358	1658
170259	5	18 17	57 22	24	27/6/97	530	830
170260	15	18 17	57 22	24	27/6/97	545	845
170261	10	18 18	57 24	24	27/6/97	1353	1638
170262	20	18 18	57 24	24	27/6/97	1406	1706
170263	5	18 20	57 24	25	28/6/97	529	829
170264	15	18 20	57 24	25	28/6/97	544	844
170265	5	18 22	57 25	25	28/6/97	1450	1650
170266	20	18 22	57 25	25	28/6/97	1502	1702
170267	5	18 24	57 29	26	29/6/97	522	822
170268	25	18 24	57 29	26	29/6/97	535	835
170269	10	18 24	57 29	26	29/6/97	1424	1654
170270	20	18 24	57 29	26	29/6/97	1436	1728
170271	10	15 59	62 00	28	1/7/97	1357	1627
170272	60	15 59	62 00	28	1/7/97	1416	1708
170273	10	16 48	60 30	31	2/7/97	928	1231
170274	70	16 48	60 30	31	2/7/97	942	1242
170275	10	17 35	59 06	34	3/7/97	726	1026
170276	70	17 35	59 06	34	3/7/97	820	1108
170277	10	17 42	57 14	37	4/7/97	640	940
170278	25	17 42	57 14	37	4/7/97	652	952
170279	5	17 47	57 35	38	4/7/97	1921	2051
170280	10	17 47	57 35	38	4/7/97	1934	2122
170281	5	17 41	57 38	39	5/7/97	527	827
170282	25	17 41	57 38	39	5/7/97	543	843
170283	10	17 35	57 40	39	5/7/97	1350	1620
170284	25	17 35	57 40	39	5/7/97	1402	1650
170285	5	17 30	57 43	41	6/7/97	541	841
170286	25	17 30	57 43	41	6/7/97	558	858
170287	10	17 26	57 45	41	6/7/97	1410	1625
170288	25	17 26	57 45	41	6/7/97	1425	1657
170289	5	17 21	57 51	43	7/7/97	538	838
170290	25	17 21	57 51	43	7/7/97	603	903

170291	10	17 15	57 58	43	7/7/97	1300	1545
170292	25	17 15	57 58	43	7/7/97	1315	1615

Appendix B: **Samples taken for analysis by flow cytometry. (P. Burkill)**

Date	Cast	Depth (m) range	MZP Herbivory	Depth (m) of experiment
15 June 1997	CTD – 03	10 – 200		
	CTD – 04	10 – 40		
	CTD – 05	10 – 200		
16 June 1997	CTD – 06	10 – 150		
	CTD – 07	10 – 150		
	CTD – 08	5 – 20		
	CTD – 09	1 – 115		
17 June 1997	CTD – 10	10 –150		
	CTD – 11	10 –150		
	CTD – 12	10 – 60		
	CTD – 13	10 – 150		
	CTD – 14	10 –150		
19 June 1997	CTD – 15	5 – 40	Dil 1	10
20 June 1997	CTD – 18	5 – 40	Dil 2	10
21 June 1997	CTD – 22	5 – 30	Dil 3	15
22 June 1997	CTD – 25	5 – 40	Dil 4	10
23 June 1997	CTD – 28	5 – 80	Dil 5	15
24 June 1997	CTD – 32	5 – 100	Dil 6	10
25 June 1997	CTD – 36	5 – 100	Dil 7	10
26 June 1997	CTD – 41	5 – 100	Dil 8	10
27 June 1997	CTD – 45	5 – 100	Dil 9	10
28 June 1997	CTD – 49	5 – 100	Dil 10	10
29 June 1997	CTD – 52	5 – 100	Dil 11	10
1 July 1997	CTD – 56	10 – 150		
2 July 1997	CTD – 60	10 –150		
3 July 1997	CTD – 61	10 – 150		
4 July 1997	CTD – 64	10 – 150		
	CTD – 65	5 – 150		
5 July 1997	CTD – 67	5 – 100	Dil 12	11
6 July 1997	CTD – 70	5 – 100	Dil 13	7
7 July 1997	CTD – 73	5 –100	Dil 14	10

Appendix C: ***Statement on data politics*** **(T. Mitzka)**

This file (Readme.doc) contains aspects of data distribution and data politics. The cruise participants and the corresponding principal investigator agree with the following statements, to bring the pilot project “Production of a cruise data CD-ROM during the cruise” to a successful end. If there any questions left, please contact the German JGOFS data manager :

Institut für Meereskunde
Thomas Mitzka — Tel: ++49-(0)431-597-3863
Düsternbrooker Weg 20 — Fax: ++49-(0)431-567568
24105 Kiel, Germany — E-Mail: Tmitzka@ifm.uni-kiel.de

General items:

1. Every principal investigator with data on the CD-ROM, will get one free.
2. If a new release of the CD-ROM will be published, every PI will get one ROM free.
3. Papers and articles can be included on every new release.
4. If data will be corrected, the PI has to inform the German JGOFS data manager.

The following items are statements of the German JGOFS data management data politics:

1. All data on this CD-ROM are preliminary and raw data.
2. All data are for comparison only, publication of foreign data is not allowed.
3. It is not allowed to give any of these data to a third person without confirmation by the principal investigator.
4. The German JGOFS data manager will not given any data away without confirmation by the PI.
5. All final data will be included into the German JGOFS data base.
6. The availability of data at the JGOFS data base will be published on the World Wide Web, inclusive the principal investigators E-mail address.
7. At the end of the German JGOFS project all data will be included into the national German oceanographic data base
8. All information about the data will be included into the international JGOFS data inventory (will be created and stored at the CPO in Bergen) and will also be included into the national German data inventory.

Appendix D: **Example of data documentation SONNE cruise 120 JGOFS Arabian Sea process study (T. Mitzka)**

If one of the following fields does not fit your requirements, leave it blank or modify to your needs.

[1] General:

Parameter: <e.g. SALINITY>
Level 1: <Yes >
Principal Investigator: <Joanna, Waniek>
Institute Address: <Institute of Marine Science, Kiel, Germany>
E-Mail Address: <Jwaniek@ifm.uni-kiel.de>

List of Parameters: <Salinity, Conductivity>
List of Units: <PSU, mS>

[2] Sampling:

Gear (e.g. CTD, RO6, MSN,....): <CTD; 10L Niskin Bottles>
Standard Depth or Standard Intervals : <e.g. 10, 30,80, 200, 800, 1000, 1500, 3000>
Chemicals : <e.g. acidified or formalin>
Special Procedures: <e.g. leave 24 hours in the lab before starting analysis>
Comments and Notes: <samples only from deep casts>

[3] Analysis:

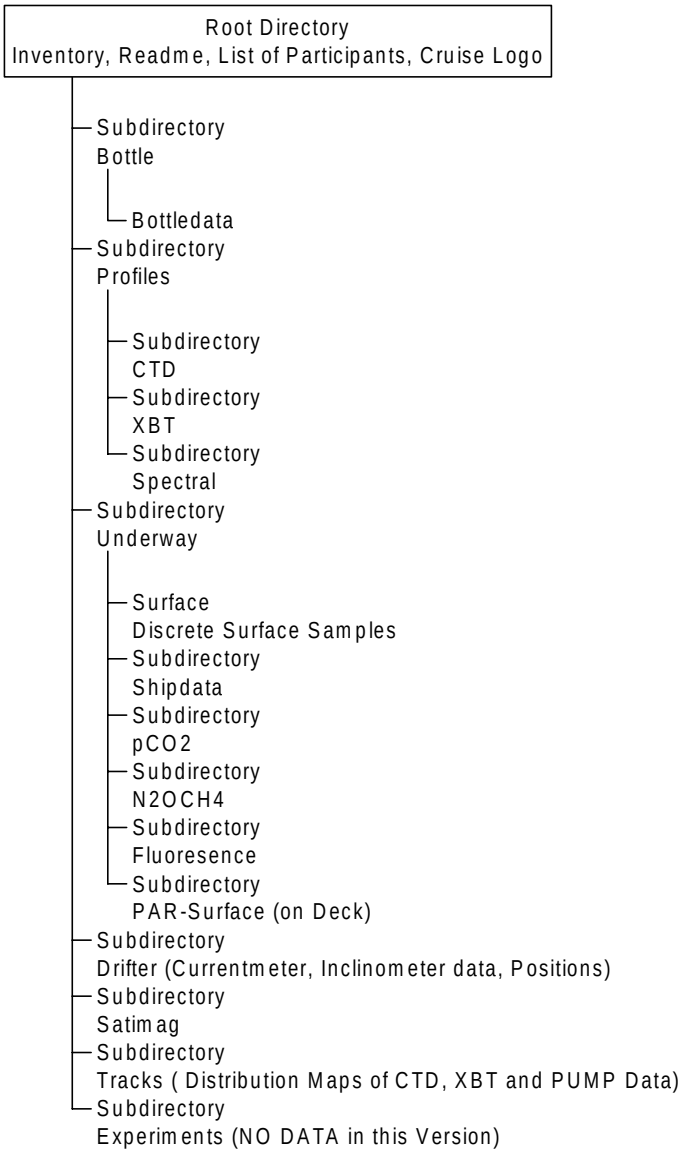
Instrument: <e.g. Bench Salinometer, Autosal 3000>
Method: <Conductivity relative to 35.0000 PSU >
Precision: <0.001 PSU>
Comments: <Temperature of Bench Salinimeter was not stable>

[4] Results:

Quality of Data: <Multiple measurements with good results>
Known Problems: <At Station 3, Cast 5, bottle 24, Diatoms affected the results>

[5] Comments:

Appendix E: **Structure of Sonne Cruise 120 CD-Rom (Raw data, release 1.1 (T. Mitzka)**



Comment:

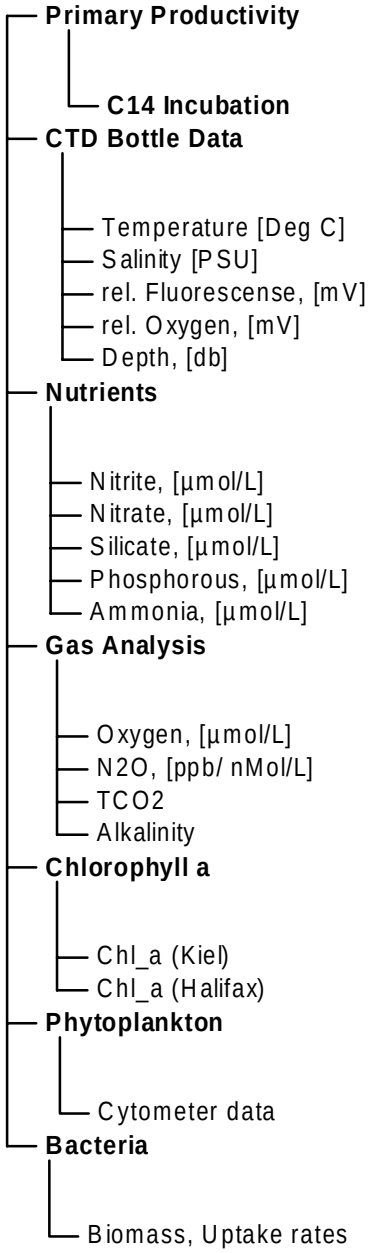
The root directory contains several files in different formats. INVENTORY.CSV, README.TXT, a list of cruise participants, an example file for data documentation and the cruise Logo. The inventory file is a collection of all station data (e.g. position, date, time, water depth, gear....) as plain ASCII values separated by comma. The ”readme” file is a general description of the structure of the CD-ROM and some notes on data politics.

All data stored in spreadsheets have got the same format:

Station No	Cast No.	Gear	Date/time	Bottle No	Depth	Value 1	Value 2	.....

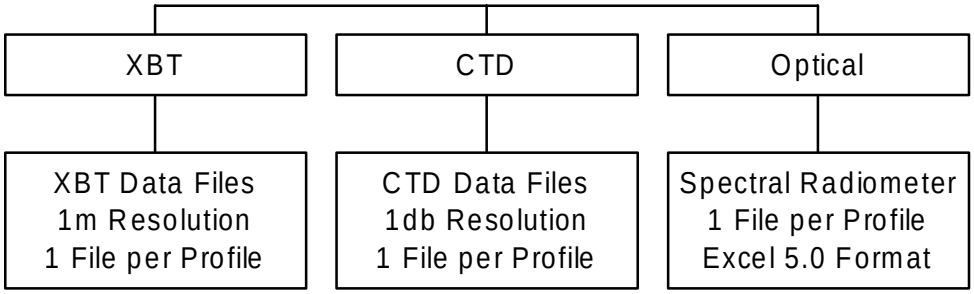
If one of the columns doesn't fit the originators spreadsheets, e.g. the samples are not from water bottles, leave the column blank or enter the necessary information and change the column description. The data documentation will be stored with the data in the same directory.

Subdirectory Bottle

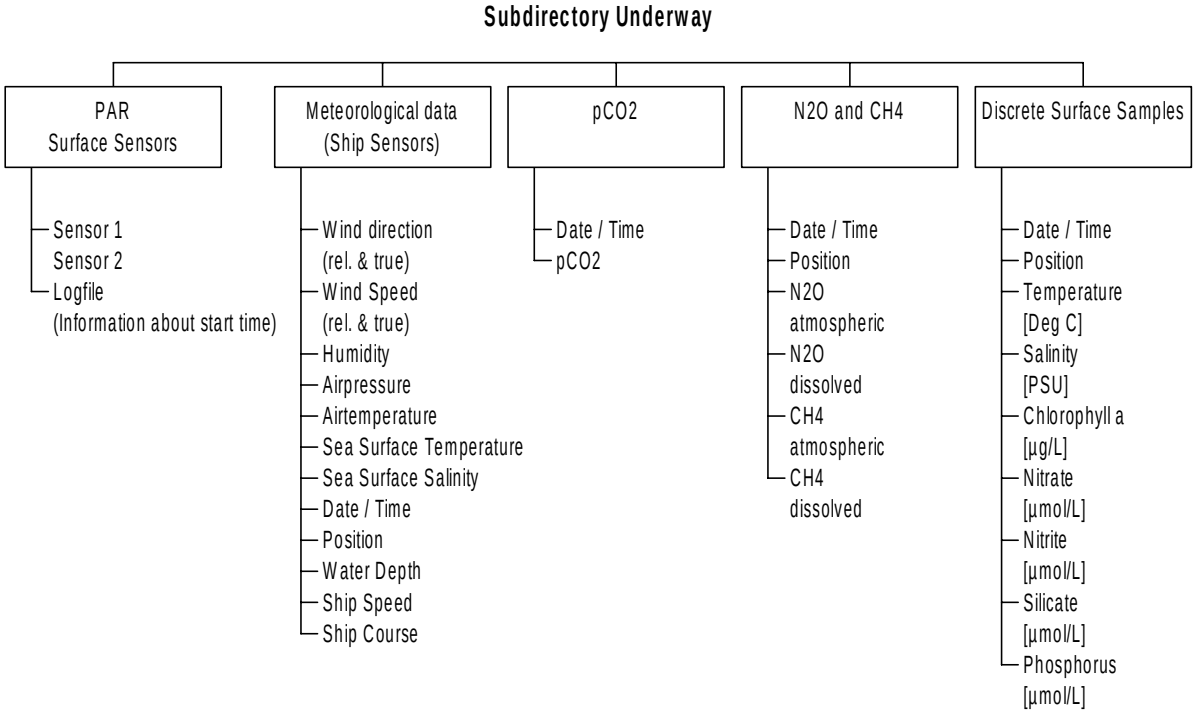


Comment: The subdirectory BOTTLE will contain several data files, each file is a plain ASCII collection of comma separated values. The data are sorted by theme, e.g. data collected by CTD, nutrient data, data from gas analysis and chlorophyll.

Subdirectory Profiles



Comment: The data documentation will be stored in the same directory as the data files.



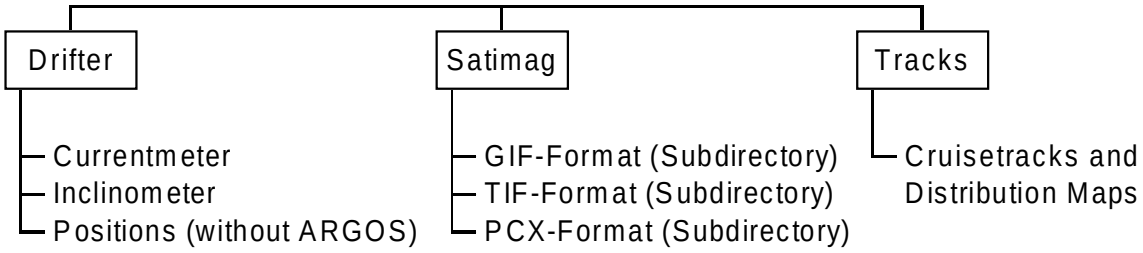
Comment:

The data collected by ship sensors are stored in ASCII files, each file contains data of a four hour interval, with a one minute resolution. The file name denotes the starting date and time of collection (MMDDHHmm). All data are uncalibrated!

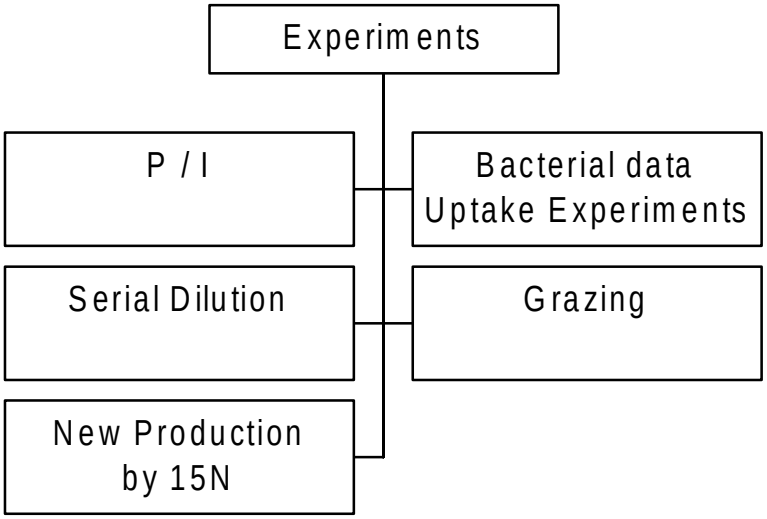
The data of the discrete surface samples are stored in several spreadsheets. Each transect has got it's own data file.

Comment:

Subdirectories Drifter, Satimag and Tracks



Subdirectory Experiments



Comment:

No Data until today, the only file is a document describing the P/I Method.