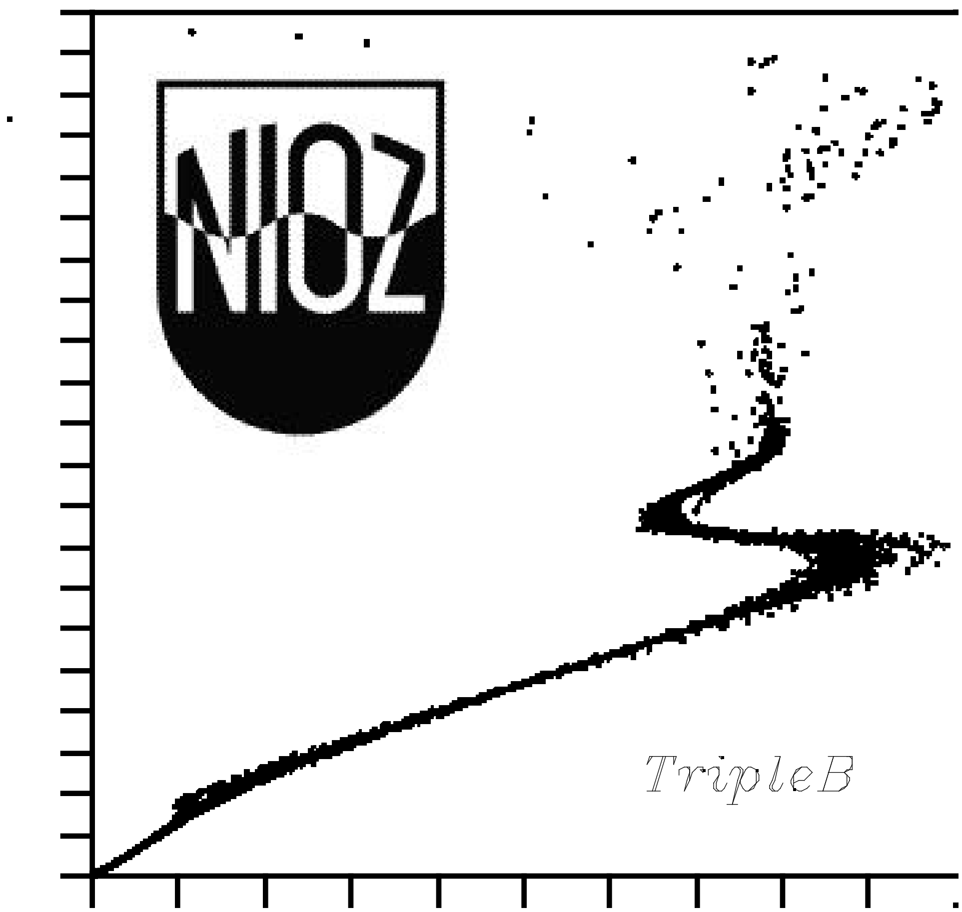
RV Pelagia Cruise Report:

Cruise 64PE122, Project TripleB,

WHP repeat area AR12

H.M. van Aken
Chief Scientist



Bay of
Biscay
Boundary

NIOZ, Texel, 1999

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1 Cruise Narrative

1.1 Highlights

a: WOCE Repeat Area AR12, RV Pelagia cruise PE122 in the Bay of Biscay

b: Expedition Designation (EXPOCODE): 64PE122

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d: Ship: RV Pelagia, Call Sign: PGRQ
length 66 m.
beam 12.8 m
draft 4 m
maximum speed 12.5 knots

e: Ports of Call: Vigo (Spain) to Vigo (Spain)

f: Cruise dates: August 18, 1998 to September 2, 1998

1.2 Cruise Summary Information

Summary

Early before noon of 18 August RV Pelagia left the quay in the Spanish port of Vigo, and headed for the Bay of Biscay. We arrived at the Biscay continental slope near Gijón in the evening of 19 August, and spent the night carrying out an echo sounder survey over the slope. The following day moorings BB22 to BB24 were recovered. Mooring BB21, deployed the previous year, was broken due to corrosion, and the upper part with two current meters was salvaged by a fisherman from Aviles, and subsequently brought to Vigo. After recovery of the moorings course was set to mooring BB20 near the Meriadzek Plateau. Underway two CTD casts were taken for test purposes, as well as one micronightly echo sounder survey, moorings BB17 to BB 20 were recovered. After recovery of the last mooring course was set to the Armorican Shelf, south-west of Brest. From there a section (A) with CTD and MSP stations was carried out towards the Spanish continental shelf near Gijón. On this section three more ARGOS drifters were deployed. Section A was finished on 26 August, and course was set to start the survey of section B, about 60 mile further eastwards. This section was surveyed from 26 to 29 August with CTD as well as with MSP casts. The survey of the final section C started at 29 August. After midnight in the morning of 31 August course was set to Vigo, while during that day the analyses of the last water samples from the rosette system and the thermo-salinograph were finished. The ship arrived in the port of Vigo in the morning of 1 September. During that day shifting of laboratory containers was started, and the transport back to Texel of the buoyancy spheres of the moorings and of a container with all current meters and computers was prepared, while the last preliminary data processing was finished. Early in the morning of 2 September the scientific crew debarked for Texel.

Cruise Track

The cruise was carried out in the Bay of Biscay. The cruise track is shown in figure 1.

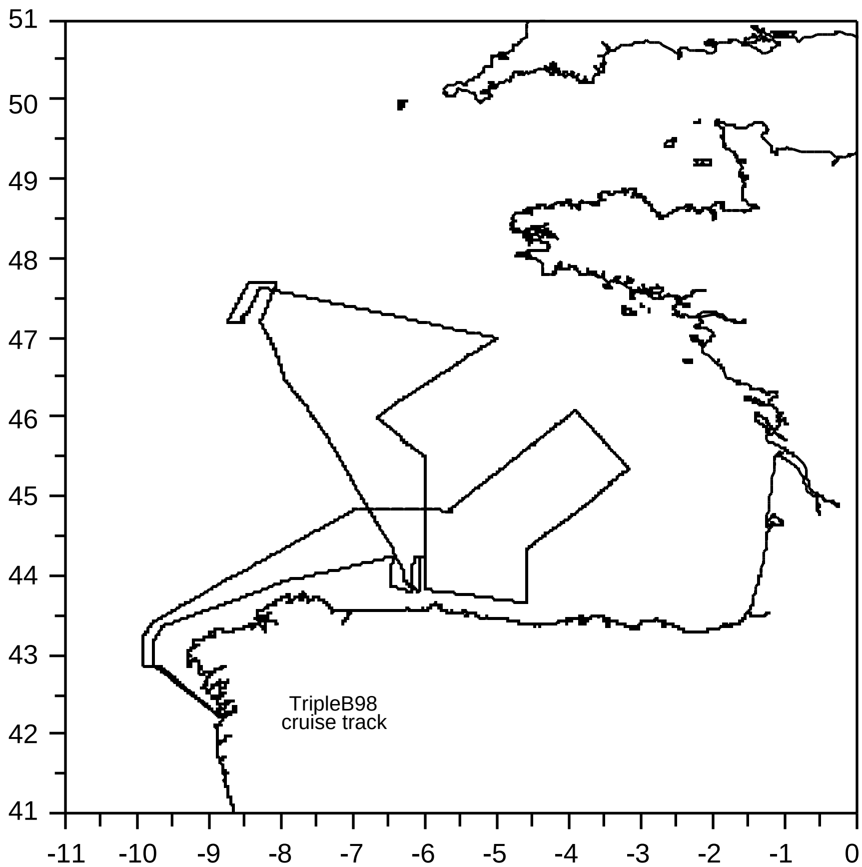


Figure 1. Cruise track of RV Pelagia cruise 64PE122

Number of Hydrographic Stations

A total of 44 CTD casts was recorded. On 42 of these casts, water samples were taken for the determinations of salinity and dissolved oxygen and nutrients. Two water samplers in the rosette system were fitted with high accuracy reversing electronic pressure sensors. The positions of the hydrographic stations are indicated in figure 2.

At the hydrographic stations the SBE9/11+ CTD was lowered with a speed of about 1 m/s. Due to the use of a bottom indicator switch we were able to sample to within quite a short distance from the bottom (5 m).

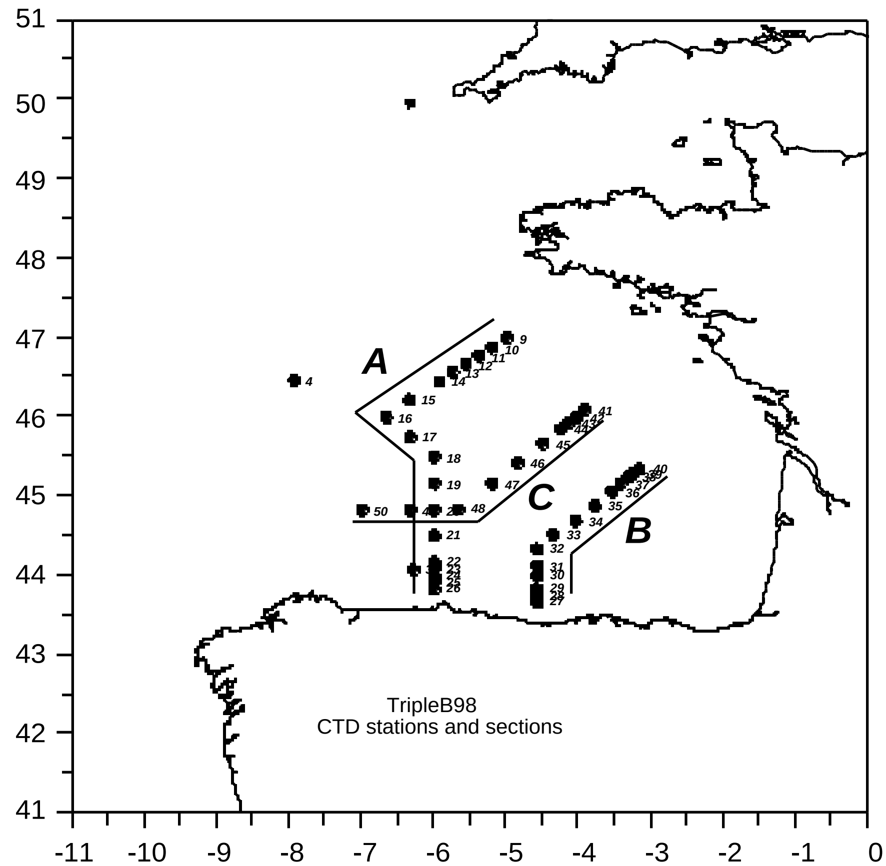


Figure 2. Distribution of hydrographic stations and sections.

Hydrographic Sampling

During the up-cast of each CTD/rosette station water up to 25 samples were taken at regular depth intervals. The samples were analysed for salinity, oxygen and nutrients. For test purposes also Dissolved Inorganic Carbon (DIC) was determined from the samples collected on section A. These latter data will not be reported further, because of their still experimental status and questionable quality.

The vertical distribution of the sampling locations is indicated in figure 3.

Micro-structure profiler casts

Along sections A, B, and C 20 micro-structure profiler (MSP) casts were carried out after the CTD cast of the stations in order to estimate turbulent intensity and dissipation. The tethered free falling probe was lowered close to the bottom, or to 1000 m, whichever was the shallowest. The distribution of the microstructure profiler casts is indicated in figure 4.

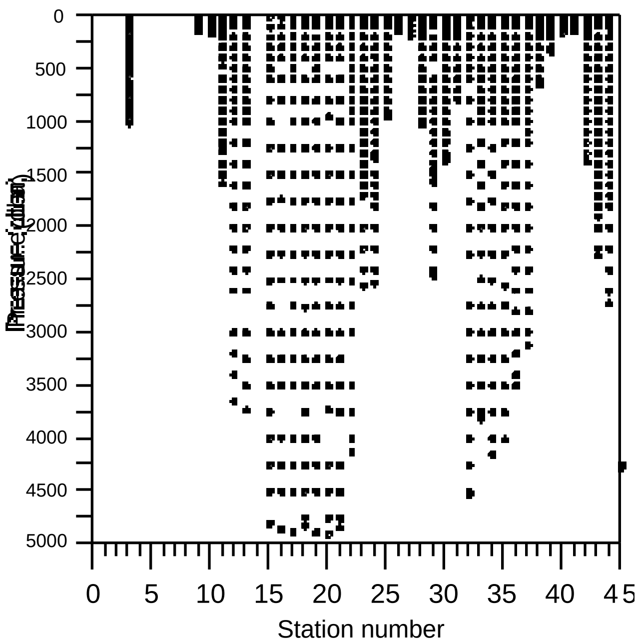


Figure 3. Vertical distribution of the water samples versus station number.

Moorings

The moorings BB17, BB18, BB19, BB20, BB22, BB23, and BB24, deployed in 1997, were recovered without problems. Two of the NBA current meters suffered from malfunctioning of the compass, while one Aanderaa RCM 8 current meter suffered from a stalled rotor. The only Aanderaa RCM 9 acoustic current meter had problems with the digitizing of the velocity components, just in the winter period. Possibly this was due to the lack of acoustic reflectors in this season.

After recovery of the current meters, their data were read and copied to the computer network of RV Pelagia. At Texel the data were processed, and corrected for the magnetic variation and clock errors. From the processed data a low-pass data set, sub-sampled every 12 hours, as well as a high-pass data set, sub-sampled every hour have been produced.

Detailed information on the moorings is given in the list in appendix B. The station and cast numbers in this list refer to the station and cast numbers end positions referred to in the *.SUM file (Appendix A). In Fig. 5 the mooring positions are indicated with crosses, and BB labels.

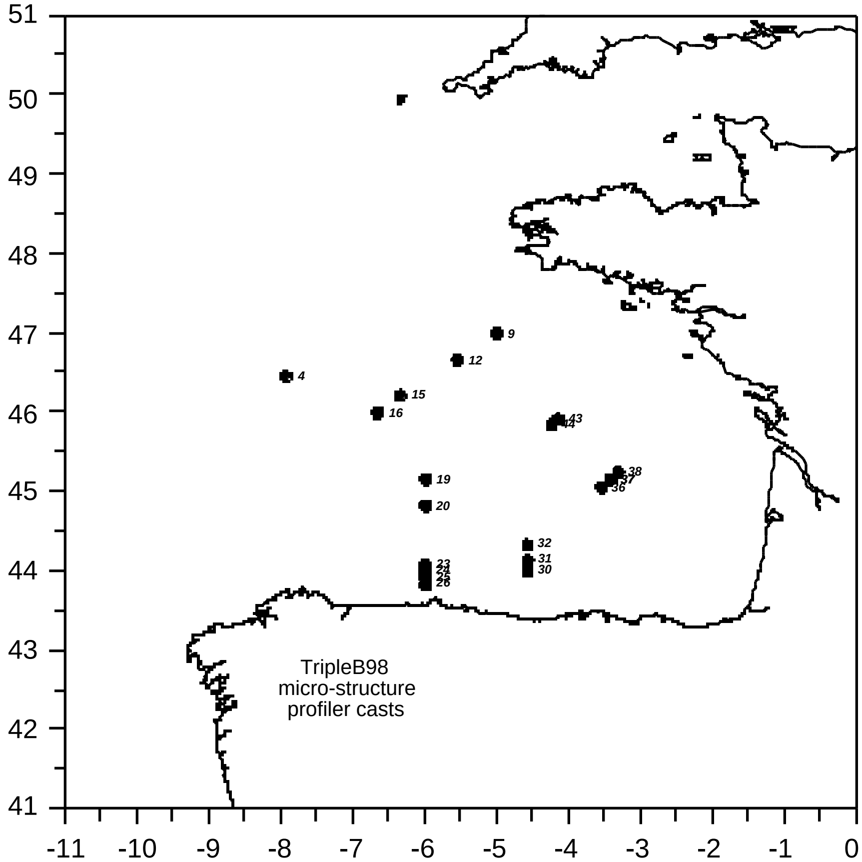


Figure 4 Distribution of stations with micro-structure profiler casts.

ARGOS drifters

During the cruise five ARGOS drifters were deployed. The drifters used were standard spherical WOCE/TOGA mixed layer drifters (diameter 30 cm), fitted with a holey sock drogue at 15 m. The drogues had a length of 7 m, and a diameter of 1 m. The ARGOS ptt numbers of the drifters are 16118 to 16122. In figure 5 the deployment positions are indicated with tilted squares and italic labels.

***.SUM file**

A hard copy of the *.SUM file describing all stations is added in the appendix A.

1.3 List of Principal Investigators

Name	Responsibility	Affiliation
Dr. H.M. van Aken	Ocean hydrography, ARGOS drifters.	NIOZ/Texel
Drs. C. Veth	micro-structure measurements.	NIOZ/Texel
Drs. J. Ligtenberg	Slope currents, current measurements	NIOZ/Texel

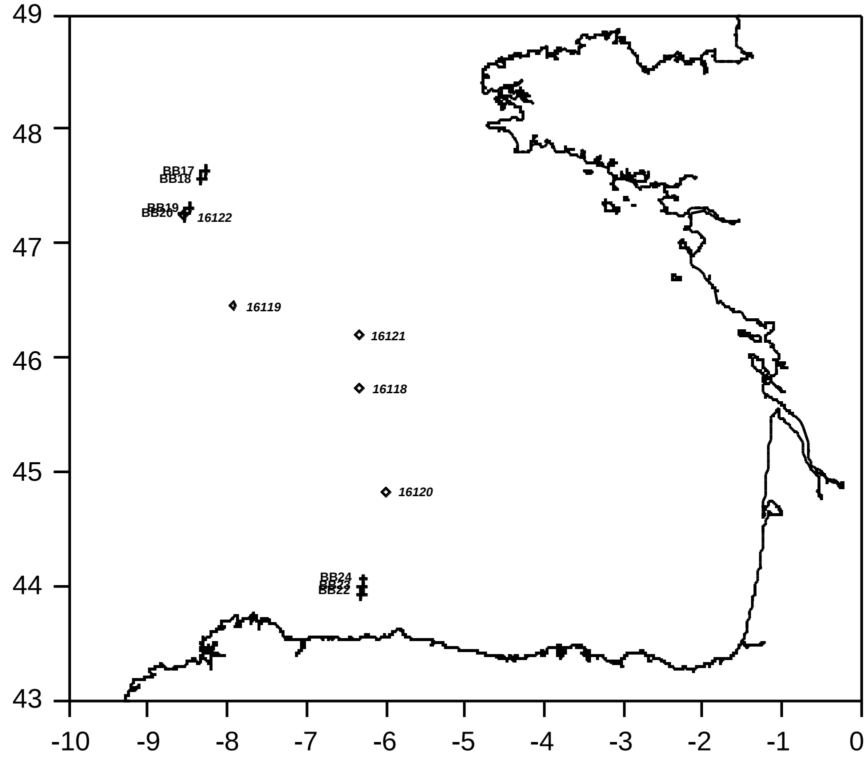


Figure 5. Positions of the recovered moorings (crosses, BB labels) and the deployed ARGOS drifters (tilted squares and italic labels).

1.4 Scientific Programme and Methods

The goal of the research carried out during the cruise was to establish the structure, course and transport of the eastern boundary current in the Bay of Biscay, as well as the hydrographic structure of the Bay of Biscay, as it is affected by the eastern boundary current. For this purpose a hydrographic survey has been carried out in the Bay of Biscay, and five ARGOS surface drifters have been deployed. Seven long term current meter moorings, deployed in 1997, were recovered. The hydrographic survey covers part of the WOCE Hydrographic Research Programme repeat area AR12, and complements the hydrographic surveys & mooring and drifter deployments, carried out in 1995, 1996 and 1997 in the Bay of Biscay in the TripleB programme.

The CTD-rosette frame was fitted with weights in order to secure a fast enough falling rate. This package was lowered with a velocity of about 1 m/s, except in the lowest 100 m, where the veering velocity was reduced. Measurements during the down-cast went on to within 5 m from the bottom, until the bottom switch indicated the proximity of the bottom. During the up-cast water samples where taken at prescribed depths, when the CTD winch was stopped. After each cast the CTD/rosette frame was placed on deck. Subsequently water samples were drawn for the determination of dissolved oxygen, nutrients, and salinity, and the readings of the reversing electronic pressure sensors were recorded.

Preliminary Results

After the cruise all CTD data have been processed and calibrated at NIOZ, Texel, as described in chapters 2 and 3. A short, preliminary overview of the results is given here. The vertical distributions of potential temperature (THETA) and salinity (CTDSAL) versus pressure (Figure 6) show much variability between 500 and 1500 dbar because of the presence of the warm and saline core of Mediterranean Sea Water (MSW) at about 1000 dbar. At a pressure of approximately 1800 dbar a number of stations have a salinity minimum caused by the presence of a core of low salinity Labrador Sea Water (LSW). Between the Eastern north Atlantic Central Water (ENACW) in the permanent thermocline and the MSW core a subsurface salinity minimum is observed at all deep stations. In the upper few tens of dbars of the water columns a wide variety of salinities is encountered with values above as well as below the salinity of the top of the underlying water.

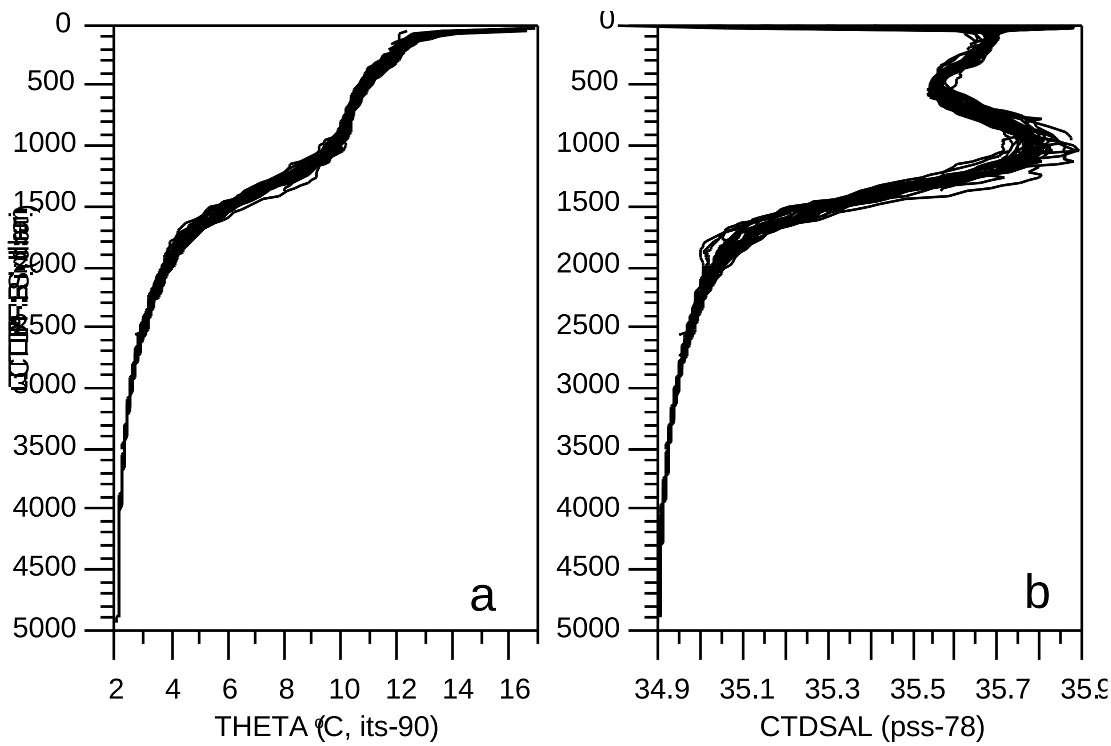


Figure 6. Profiles of (a) potential temperature (THETA) and (b) salinity (CTDSAL) versus pressure (CTDPRS)

The Θ-S diagram (Figure 7a) confirms the presence of ENACW at potential density anomalies γ in the approximate range 27.05 < γ(Θ,S) < 27.25 kg/m^3, whereas MSW is found in the density range 27.25 < γ(Θ,S) < 27.75 kg/m^3. LSW with Θ ≈ 3.6°C and S ≈ 35.0 is found at a potential density anomaly of about 27.8 kg/m^3. The vertical distribution of potential vorticity (Figure 7b) shows that potential vorticity minima (the Mode Water of the previous winter?) are found near the γ(Θ,s) = 27.10 kg/m^3 isopycnal near the top of the permanent thermocline. At the density levels of the LSW and below the potential vorticity reaches even lower values. At the lowest levels the water approaches a potential temperature Θ ≈ 2.0°C and a salinity S ≈ 34.90, characteristic for Lower Deep Water (LDW).

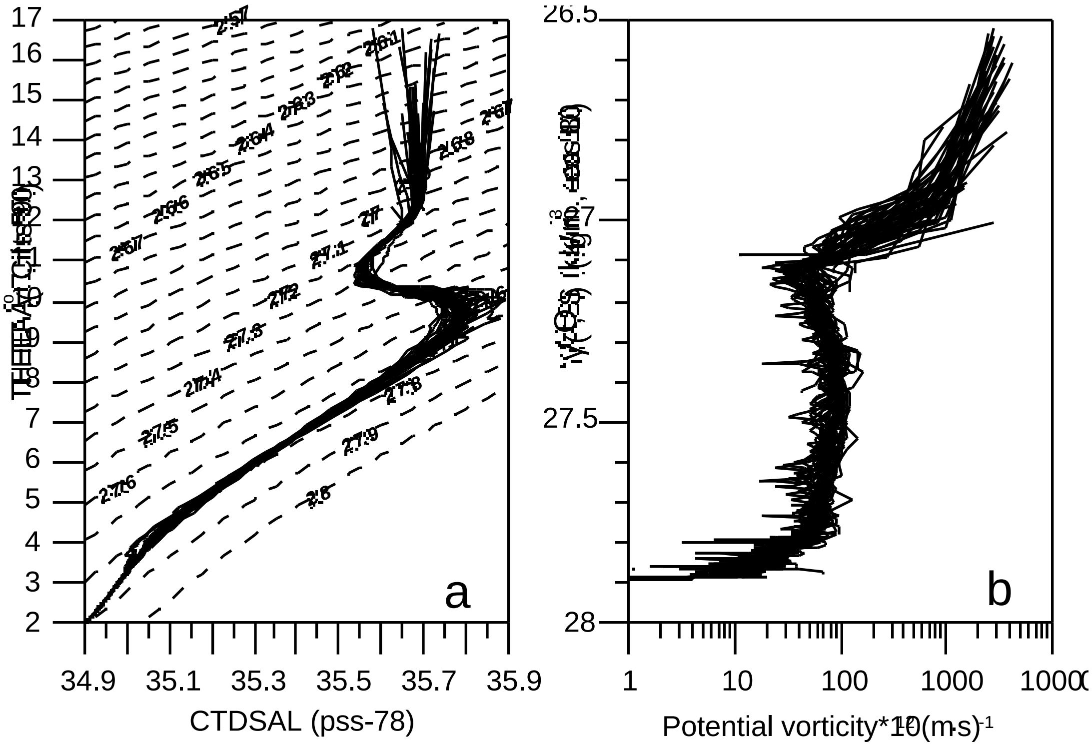
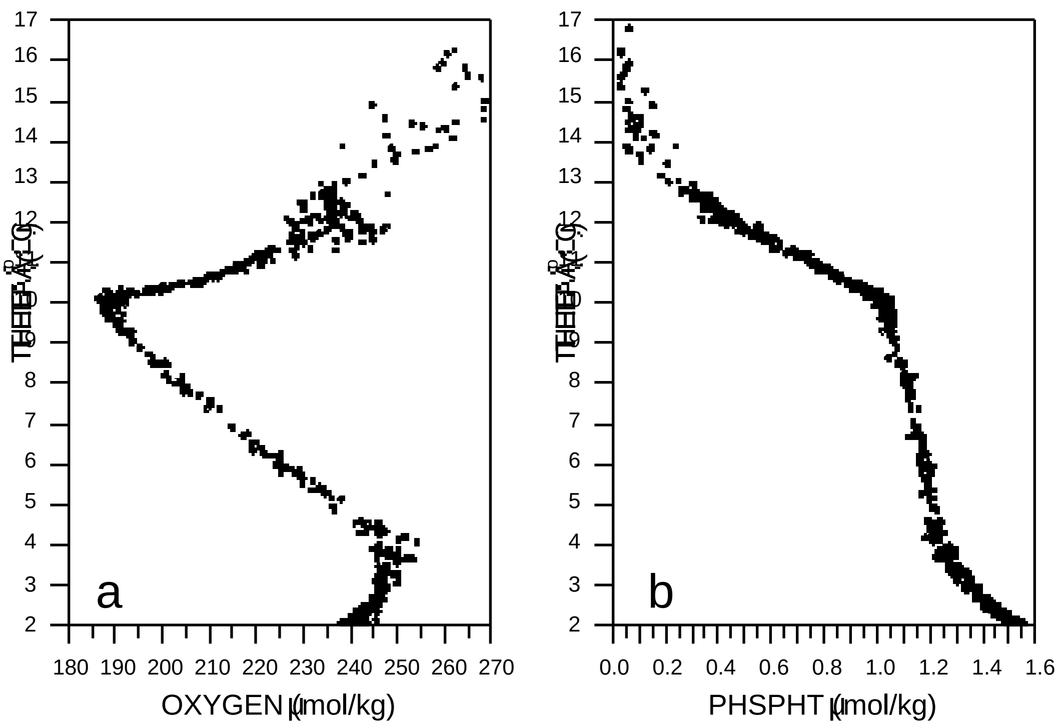


Figure 7. Θ-S diagram (a) and plot of baroclinic potential vorticty versus potential density anomaly (b) for all CTD casts. The dashed lines in (a) depict lines of constant potential density anomaly.



|Figure 8. Plots of dissolved oxygen (a, OXYGEN) and dissolved phosphate (b, PHSPHT) versus potential temperature (THETA).

The distribution of the non-conservative parameters also reflect the known water mass structure. The plot of dissolved oxygen versus potential temperature (Figure 8a) shows an oxygen minimum coincident with the MSW core near Θ = 10°C, a maximum near the LSW core with Θ = 3.6 to 4.0°C, and a near bottom minimum at LDW temperatures (Θ = 2.0°C). At temperatures characteristic of the top of the permanent thermocline and the Mode Water (12 to 13°C) the O_2-Θ line shows a shift towards relatively lower oxygen concentrations in the seasonal thermocline. The distribution of the nutrients in temperature space (Figures 8b and 9) shows a similar structure with inflexion points at the levels of the MSW and LSW cores, and near bottom maxima connected with the LDW. At the highest temperatures, close to the sea surface, the nutrient concentrations approach zero because of the nutrient use during primary production.

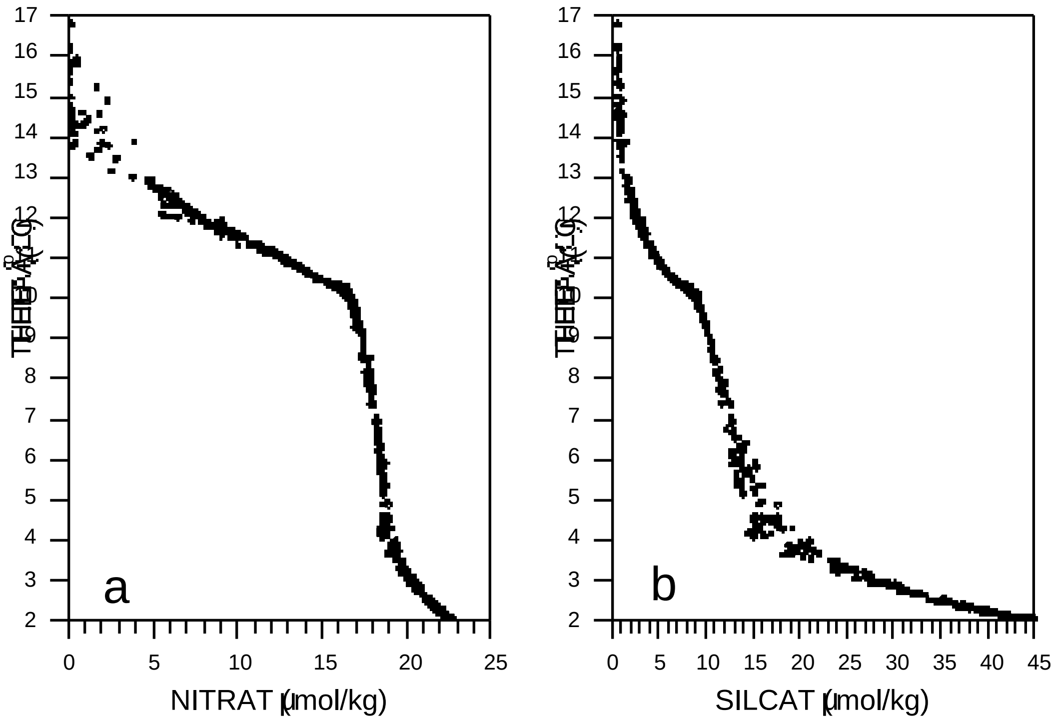


Figure 9. Plots of dissolved nitrate (a, NITRAT) and dissolved silica (b, SILCAT) versus potential temperature (THETA).

The dissolved nutrients show a more or less one to one relation (Figure 10). This relation is however not linear over the whole range of concentration values, but parts of the nutrient relations can be approximated by linear relations with a constant empirical stochiometric ratio. This applies to the water column above the MSW core, where ΔP:ΔN:ΔSi = 1:16.5:5.5, and the water column below the LSW core, where ΔP:ΔN:ΔSi = 1:13:90. Most probably these ratios are not solely determined by the ratios in which the nutrients are consumed or produced in fixed ratios in biochemical processes (and dissolution for silica), but also by mixing of the different water masses with their different characteristic in situ and pre-formed nutrient concentrations. Especially in the deep water mass the very high dissolved silica concentration of the LDW core due to the contribution of Antarctic Bottom Water to this near bottom water mass is responsible for the low ΔP:ΔSi ratio.

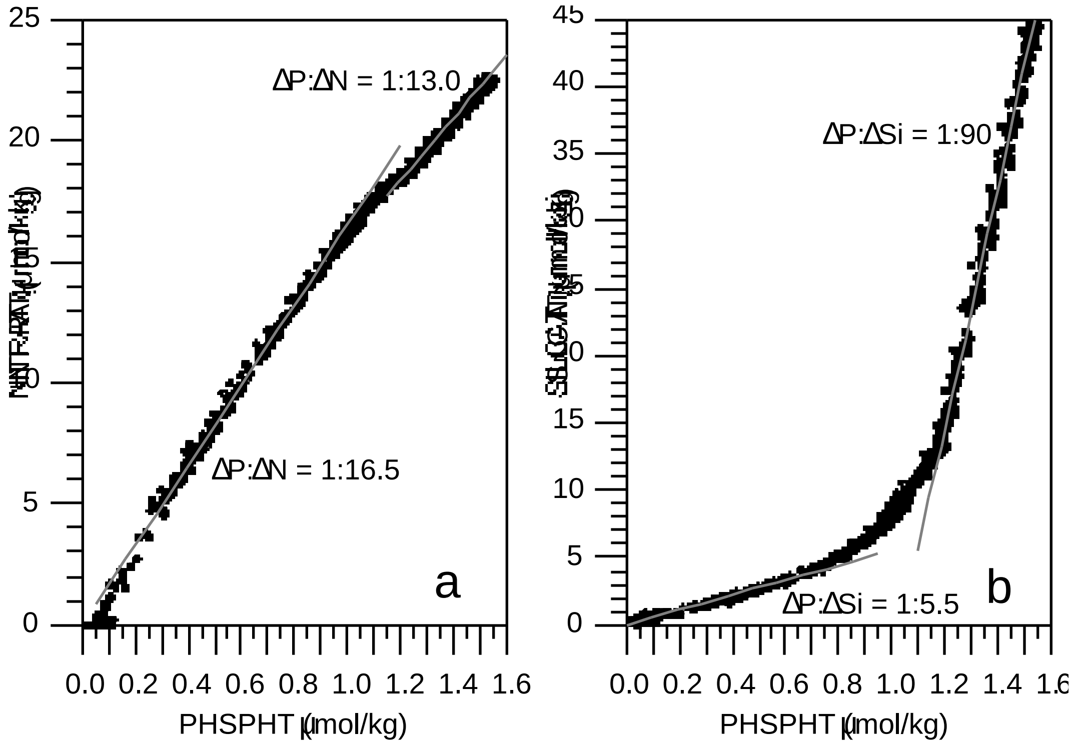


Figure 10. Plots of the concentrations of dissolved nitrate (a, NITRAT) and silica (b, SILCAT) versus the concentration of dissolved phosphate (PHSPHT). The straight lines indicate linear dependencies according to the empirical stochiometric ratios given in the figures.

The Sea Surface Temperature (SST) from the continuously recording thermo-salinograph (Figure 11) shows temperatures of over 22 °C close to the Spanish coast near 5°W. As in 1997 relatively low temperatures (SST < 18 °C) were encountered near the continental slope south-west of Brittanny. The lowest surface temperatures (SST < 16°C) were observed over the continental slope near western Galicia where upwelling took place. The Sea Surface Salinity (SSS) in the central Bay of Biscay shows values of over 35.8, while near the continental slope and shelf lower salinities have been observed (Figure 12). Also the sea surface oxygen concentration was observed with the continuously recording measurement system. From these data the Apparent Oxygen Utilization (AOU) was determined. The AOU values of the surface water were nearly everywhere negative, of the order of 5 to 10 µmol/kg. (Figure 13). This reflects a slight over-saturation of the surface water, probably due to primary production in the surface layers. In the upwelling area off western Galicia AOU values in the surface water of over 40 µmol/kg were observed.

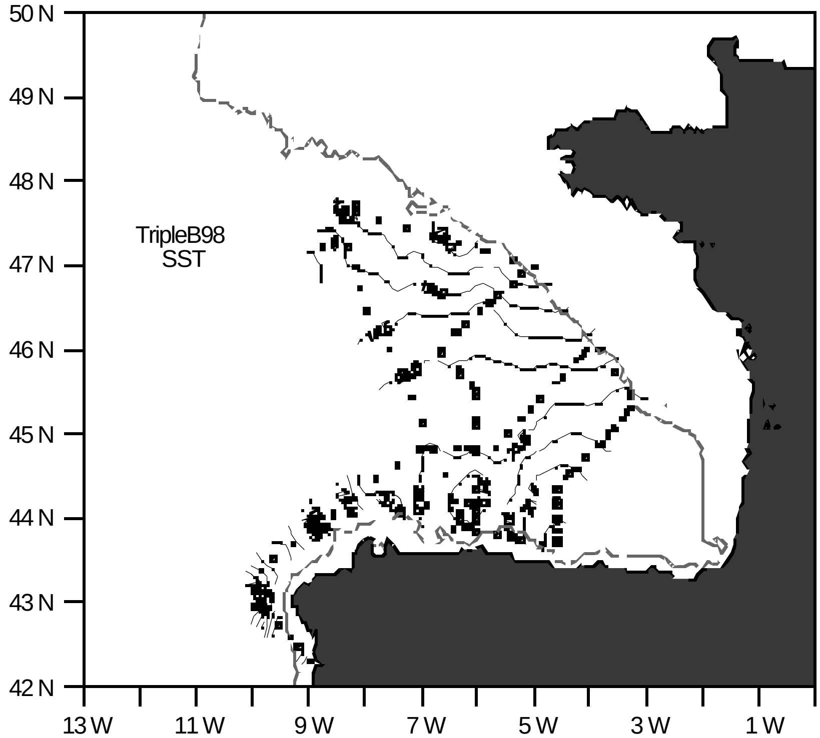


Figure 11. Horizontal distribution of the Sea Surface Temperature (SST) measured with the AQUAFLOW thermosalinograph system. The thick line indicates the 200 m isobath which coincides with the position of the upper continental slope. The dots show the hourly positions of RV Pelagia.

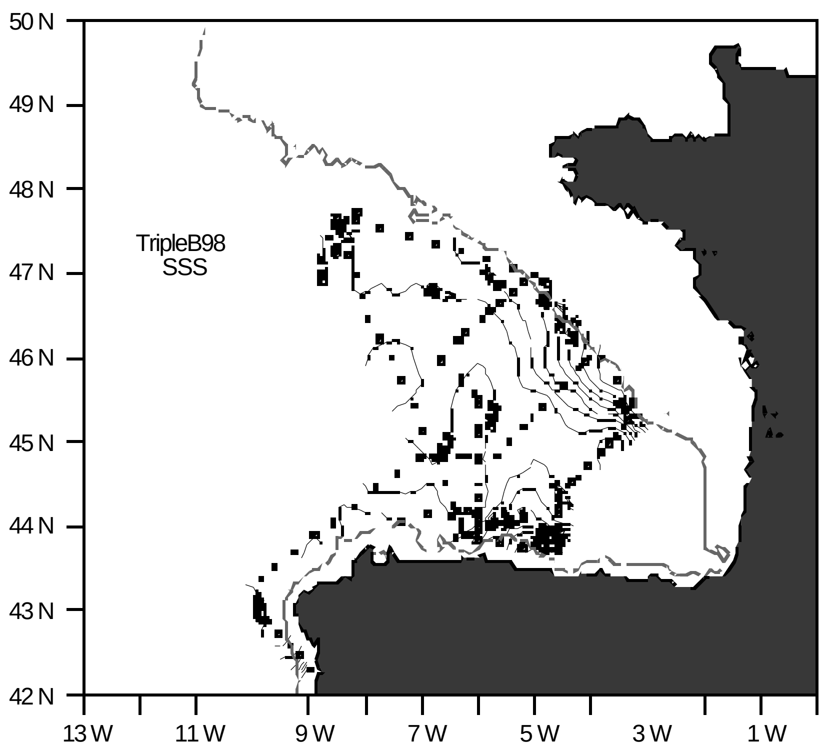


Figure 12. The horizontal distribution of the Sea Surface Salinity (SSS) as measured with the thermosalinograph system. The thick line indicates the 200 dbar isobath, and the dots the hourly positions.

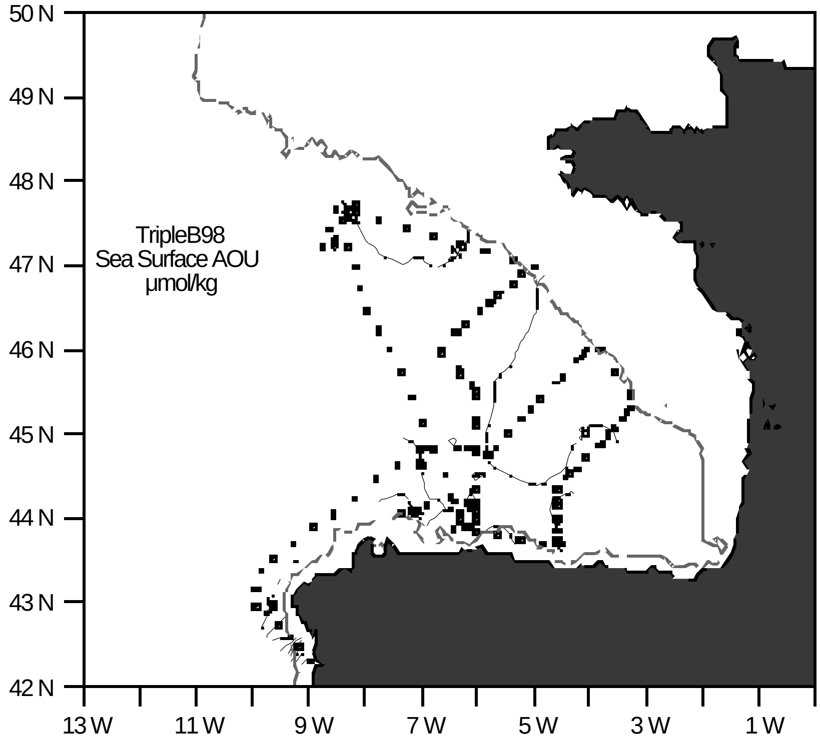


Figure 13. Horizontal distribution of the Sea Surface Apparent Oxygen Utilization (AOU) derived from the oxygen concentration as measured with the AQUAFLOW thermosalinograph system. The thick line indicates the position of the 200 m isobath, and the dots the hourly positions.

1.5 Major Problems Encountered during the Cruise

With the recovery of the current meter moorings it appeared that pit corrosion had seriously affected the stainless steel tow bars of some NBA current meters, as well as the frame of the ADCP. With all affected tow bars it appeared that the PVC isolator, mounted to prevent direct contact between tow-bar and swivel bolt was damaged, due to wear. This caused direct contact between the tow bar and the stainless steel bolt in the tow bar, suggesting an electrochemical cause of the corrosion. Corrosion of the tow bar at the side of the swivel was also the cause of the partial loss of mooring BB21. The future use of different types of stainless steel and/or insulators in moorings should be re-considered.

The rotating tow link between the winch cable and the CTD twice gave an electrical shortcut. Both times it was caused by sea water entering the link due to leakage. By fast repair as well as the use of a spare tow link the problems were solved easily. The use of another type of tubing in the tow link should be considered.

Although the throughput in oxygen samples per day with the spectro-photometer is considerably larger than with the automated Winkler titration used during previous cruises, a first comparison of duplicate samples suggests that the spectro-photometer is considerably less precise. But the RMS of the difference between the duplicate (O(1.0 µmol/dm^3)) is considerably less than the oxygen signal in the water column (O(90 µmol/dm^3)). A further analysis, with regard of the applicability of the spectro-photometer and other new methods for the high precision determination of oxygen has to be made at

Some minor problems turned up with the computer network and the recording of underway sampling. The automated backup of the underway data used backup tapes in a much faster rate than intended. The cause of this feature should be found and repaired. Halfway the cruise the signal from the air temperature sensor disappeared. The cause could not be found, and is considered to be located in the meteorological interfaces, supplied by KNMI. Documentation for repair of the interface was not available, and should be obtained. The fluorescence channel of the underway monitoring system only gave erroneous white-noise-like data as it did in 1997. Maintenance of this sensor should be reconsidered. The echo sounder could not always digitize the depth because of blurred echoes over steep and deep slopes. However the new software used for the recording of underway sampling then always recorded the previous value instead of an error value. The new software should be reconsidered in co-operation with scientific users of the data.

1.6 Lists of Cruise Participants

Scientific crew

person	**responsibility**	**Institute**
H.M. van Aken	Chief Scientist, ARGOS drifters, Data management	NIOZ
D. van As	Salinity determination	IMAU
K. Bakker	Nutrient & DIC determination	NIOZ
M. Bakker	Mooring technology & maintenance	NIOZ
R.L. Groenewegen	Acoustic releases, Electronics	NIOZ
M. Hiehle	Salinity determination	NIOZ
M.T.J. Hillebrand	Current meters, Hydro watch	NIOZ
R.X. de Koster	Data management, Hydro watch	NIOZ
J. Ligtenberg	Data processing current meters, Hydro watch	NIOZ
Y. Muilwijk	Hydro watch	IMAU
S. Ober	ADCP, Hydro watch	NIOZ
M. Smit	Oxygen determination	UT
A. van Veldhoven	Oxygen determination	IMAU
C. Veth	Current Meters, Hydro Watch	NIOZ
L. Wuis	Mooring Technology & maintenance	NIOZ

NIOZ: Netherlands Institute for Sea Research, Texel

IMAU: Institute for Marine and Atmospheric Research, Utrecht University

UT: Faculty of Civil Engineering and Management, Twente University

Ships crew

J. J. Jongedijk	captain

M.D. van Duijn	first mate
H.A.M. Douma	second mate
J. Pieterse	first engineer
J. Seepma	second engineer
H. de Vries	cook
P.W. Grisnicht	sailor AB
P.-W. Saalmink	sailor AB
C.T. Stevens	sailor AB
E.W. Weuring	sailor AB

2 Underway Measurements

2.1 Navigation

Differential GPS receiver for the determination of the position. The data from the receiver were recorded every ten seconds in the underway data logging system. After removal of a few spikes these data were sub-sampled every minute.

2.2 Echo Sounding

The 3.5 kHz echo sounder was used on board to determine the water depth. The uncorrected depths from this echo sounder were recorded in the underway data logging system. Over the steepest parts of the continental slope the depth digitizer of the echo sounder was occasionally not able to find a reliable depth.

Preceding the recovery of the current meter moorings one 2 or 3 lines were surveyed to determine the mooring sites, complementary to the echo sounder surveys of the mooring sites carried out in 1997. During these surveys the echo sounder data were also recorded on paper chart in order to allow hand digitizing over the parts of the slope where the automatic digitizing failed.

2.3 Thermo-Salinograph Measurements

The Sea Surface Temperature, Salinity, and dissolved Oxygen concentration were measured continuously with an AQUAFLOW thermo-salinograph system with the water intake at a depth of about 3 m. For the calibration of the salinity sensor and the oxygen sensor, water samples were taken three times per day.

2.4 Meteorological data

Air temperature and humidity, relative wind velocity and direction as well as air pressure were measured and recorded by the underway logging system. During part of the cruise the air temperature recording failed.

3 Hydrographic measurements - Descriptions, Techniques, and Calibrations

3.1 Rosette Sampler and Sampler Bottles

A 25 position rosette sampler was used, fitted with 5 and 10 litre NOEX sampler bottles. A multi-valve system, developed at NIOZ, allowed closing the sampler bottles by computer command from the CTD operator. The general behaviour of the samplers was good. Only a few samples are considered to be suspect because of sampler failure. No errors in the functioning of the rosette sampler itself could be detected, except a failure of the electric motor. This could be solved easily by installing a spare motor.

3.2 Pressure Measurements

On sampler bottles 2 and 7 thermometer racks were mounted, fitted with SIS high accuracy reversing electronic pressure sensors. Sampler 2 contained two such pressure sensors, sampler 7 only one. Before the cruise these sensors were calibrated at the national calibration facility of the Van Swinden Laboratory of the Netherlands Measuring Institute (NMI). On deck, prior to the CTD the sensors automatically recorded the air pressure and used this air pressure for further correction of the sea pressure. These pressure values have been reported as REVPRS. The duplicate values of REVPRS from sampler 2 indicated a RMS (Root Mean Square) of the difference between both SIS pressure sensors of 0.7 dbar. Comparison of the REVPRS values with the pressure, measured with the CTD (CTDPRS) revealed a pressure dependent pressure difference (2.5 dbar/5000 dbar). This is probably due to a slight difference between the NMI calibration facility and the pressure calibration used by the manufacturer of the SBE CTD. Since the specifications of the NMI facility are considered to be better, it was decided to correct CTDPRS with a linear correction. After applying this calibration to CTDTMP the RMS of the difference REVPRS-CTDPRS amounts to 0.6 dbar (73 samples).

3.3 Temperature Measurements

Mounted on the CTD-rack was a high precision SBE35 reference temperature sensor, which recorded the temperature every time a sampler was closed. The zero point of this temperature sensor has been calibrated regularly by means of an H_2O triple point cell. Comparison of the primary CTD temperature sensor with the SBE35 sensor indicate that the temperatures, measured with the CTD is very close to the reference temperature. The temperature measured with the SBE35 sensor have been reported as the parameter REVTMP.

The temperatures, measured with the CTD during sampling were first corrected for its known pressure dependence (0.7 mK/5000 dbar). These corrected values (CTDTMP) were then compared with REVTMP. the scatter of the difference between both temperature showed a strong decrease with increasing pressure, probably due to the decreasing errors caused by the vertical temperature gradient. The mean difference between REVTMP-CTDTMP for all samples taken at levels below the 3000 dbar surface (117 samples) amounted to 0.2 mK, with a RMS of the difference of only 0.8 mK. It was decided not to apply any further temperature correction for CTDTMP.

3.4 Salinity Measurements

Water was drawn from the samplers into a 0.5 litre glass sample bottle for the salinity determination after 3 times rinsing. The sample bottles had a massive rubber stopper as well as a screw lid. Salinity of water samples (SALNTY) was determined on board by means of an Guildline Autosal 8400A salinometer. The salinometer was used in a laboratory container, fitted with an air conditioning system. This kept the surrounding air temperature constant within 1°C. The readings of the instrument were performed by computer, giving the average and statistics of 10 consecutive readings. For each sample 3 salinity determinations were carried out. The OSI standard water used was from batch P133 with a K_{15} ratio of 0.99986 (S=34.995), prepared at 11 November 1997.

From each deep CTD/rosette cast an extra duplicate sample was drawn. Salinity determinations from the duplicate samples obtained from independent runs were used to determine the reproducibility of the salinity determination. The RMS difference between the SALNTY duplicate samples amounted to 0.0006.

SALNTY was compared with the salinity reading from the CTD (CTDSAL). The mean difference SALNTY-CTDSAL amounted to –0.0005. It was decided to apply an offset correction to the salinities, measured with the CTD. The scatter of the difference between SALNTY and the corrected CTDSAL showed a clear pressure dependence, probably because of the downward decrease of the vertical salinity gradient. For all samples taken below the level of the 3000 dbar surface the RMS difference SALNTY- CTDSAL amounted to 0.0010, with a mean difference of 0.0000 (66 samples).

3.5 Oxygen Measurements

For the oxygen determination water samples were drawn in volume calibrated 120 ml pyrex glass bottles. Before drawing the sample each bottle was flushed with at least 3 times its volume. When the samples were drawn the temperature of the sample was determined. The determination of the volumetric dissolved oxygen concentration of water samples was carried out by means of a spectro-photometer Winkler technique, recently developed at NIOZ [see Su-Chen Pai et al., Marine Chemistry 41 (1993), 343-351]. Before and after the cruise the spectro-photometer were inter-calibrated with a was prepared and calibrated in the laboratory by using gravimetric methods. The stock solutions were stored at low temperature (~4°C).

The inter-calibration with the automatic end point calibration revealed a systematic difference with the spectro-photometer values of 0.6 μmol/dm^3. The oxygen data were corrected for this difference, and a sea water blank of also 0.7 μmol/dm^3, determined during earlier TripleB cruises, was subtracted consequently. At each cast duplicate samples were taken from the deepest and shallowest sampler, and occasionally from a sampler at an intermediate level. The RMS of the differences between the duplicate samples amounts to 0.77 μmol/dm^3.

From the volumetric oxygen concentration in μmol/dm^3 the densimetric oxygen concentration in μmol/kg (OXYGEN) was determined by dividing by the sample density at sample temperature and salinity.

3.6 Nutrient Measurements

From all sampler bottles samples were drawn for the determination of the nutrients silica, nitrite, nitrate and phosphate. The samples were collected in polyethylene sample bottles after three times rinsing. The samples were stored dark and cool at 4°C. All samples were analysed for the nutrients silicate, phosphate, nitrate and nitrite within 10 hours with an autoanalyzer based on colorimetry. The lab container was equipped with a Technicon TRAACS 800 autoanalyzer. The samples, taken from the refrigerator, were directly pored in open polyethylene vials (6ml) and put in the auto sampler-trays. A maximum of 60 samples in each run was analysed.

The different nutrients were measured colorimetrical as described by Grashoff (1983);

- Silicate reacts with ammoniummolybdate to a yellow complex, after reduction with ascorbic acid the obtained blue silica-molybdenum complex was measured at 800nm (oxalic acid was used to prevent formation of the blue phosphate-molybdenum).
- Phosphate reacts with ammoniummolybdate at pH 1.0, and potassiumantimonyltartrate was used as an inhibitor. The yellow phosphate-molybdenum complex was reduced by ascorbic acid to blue and measured at 880nm.
- Nitrate was mixed with a buffer imidazole at pH 7.5 and reduced by a copperized-cadmium coil (efficiency> 98%) to nitrite, and measured as nitrite (see nitrite). The reduction-efficiency of the cadmium-column was measured in each run.
- Nitrite was diazotated with sulphanilamide and naftylethylenediamine to a pink coloured complex and measured at 550nm.
- The difference of the last two measurements gave the nitrate content

Calibration standards were prepared by diluting stock solutions of the different nutrients in the same nutrient depleted surface ocean water as used for the baseline water. The standards were kept dark and cool in the same refrigerator as the samples. Standards were prepared fresh every two days. Each run of the system had a correlation coefficient for the standards off at least 0.9998. The samples were measured from the surface to the bottom to get the smallest possible carry-over-effects. In every run a mixed control nutrient standard containing silicate, phosphate and nitrate in a constant and well known ratio, a so-called nutrient-cocktail, was measured, as well as control standards, sterilized in an autoclave or gamma radiation. These standards were used as a guide to check the performance of the analysis and the gain factor of the autoanalyzer channels. The reduction-efficiency of the cadmium-column in the nitrate lane was measured in each run.

The autoanalyzer determined the volumetric concentration (μmol/dm^3) at a temperature of 20 °C. In order to obtain the densimetric concentration in μmol/kg the volumetric concentrations were divided by the density of sea water at 20°C, sample salinity, and zero sea pressure.

Duplicate measurements carried out on the deepest sample from each cast gave RMS values of the differences of 0.19 μmol/kg, 0.01 μmol/kg, 0.16 μmol/kg, and 0.03 μmol/kg for respectively dissolved silica (SILCAT), nitrite (NITRIT), nitrate (NITRAT), and phosphate (PHSPHT). Possible variations in the gain factor of the different channels of the autoanalyzer were determined by means of the nutrient cocktail (phosphate), the autoclave sterilized standard (nitrate), and the gamma ray sterilized standard (silica). A gain factor correction, applied to the duplicate samples, resulted in a reduction of the RMS of the duplicate differences to respectively 0.14 μmol/kg (SILCAT), 0.13 μmol/kg (NITRAT), and 0.02 μmol/kg (PHSPHT). Thereupon the determined gain factors were applied to all SILCAT, NITRAT and PHSPHT values.

3.7 CTD Data Collection and Processing

The SBE 9/11+ CTD was fitted with temperature sensor SN1219 and conductivity sensor SN1046. For the data collection SEASAVE software, version 4.218, supplied by SBE, was used. The CTD data were recorded with a frequency of 24 data cycles per second. On-line a correction was applied for the sampling time difference due to the forced flushing through a tube system between temperature and salinity sensor. After each CTD cast the data were copied to a hard disk of the ship's computer network, and a daily back-up copy was made on tape. Back on Texel these data have been downloaded into the NIOZ computer network, via the network connection in the harbour. Separate copies of the back up were taken directly from Vigo to Texel.

The up-cast data files were sub-sampled to produce files with CTD data corresponding to each water sample, taken with the rosette sampler. After the determination of the final calibration of the CTD system these values were corrected accordingly.

After the cruise the raw down-cast CTD data were processed with the SEASOFT software supplied by SBE. A correction was applied for the temperature change between the temperature and conductivity sensor due to heat exchange with the flushing tube and conductivity sensor, and for different response times of both sensors. The correction factors for these corrections were determined empirically from CTD stations over the continental shelf. At these stations the vertical temperature gradient in the seasonal thermocline were largest, and so were the resulting salinity spikes. The correction settings, determined for the 1997 TripleB data appeared to be adequate for the corrections. Time series of mean values of the readings were produced for 0.5 s time intervals (bins). This is, given the typical veering velocity of about 1 m/s equivalent to an approximate pressure interval of 0.5 dbar. Consecutively the parameter values in physical units were determined using the final calibration constants.

It appeared that the SEASOFT software did not remove all spikes in the data record. Therefore the remaining spikes were removed by applying a median filter over 5 consecutive 0.5 s time bins. Hereafter the time series was filtered with a running mean over 5 time bins. Finally the time series were interpolated on equidistant 1 dbar pressure intervals, only using data without pressure overlap due to varying vertical motion of the CTD probe. Since no pressure bin averaging was applied, the NUMBER of OBS. in the *.CTD files was set by default to 12, the typical number of individual data point used to obtain the time series 0.5 s time bins which were used for the interpolation at equidistant pressure levels.

3.8 Micro-structure profiler measurements.

The micro-structure profiler used is a model FLY II manufactured by Sy-Tech Research Ltd. This instrument is tethered to a kevlar cable with electrical connector. A line puller supplies enough cable to allow a free fall of the instrument with a velocity of approximately 1 m/s. The FLY contains two perpendicular shear probes which are sampled with 280 Hz. Additionally the pressure, temperature, conductivity, and two tilt components are sampled with lower frequency (20 Hz). The instrument was lowered from the stern, while the ship had a speed of about 0.5 knots, propelled by the bow thruster. The maximum operational depth of the FLY II amounts to 1000 m.

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Appendix A

cruise summary (*.SUM file) of Pelagia cruise 64PE110