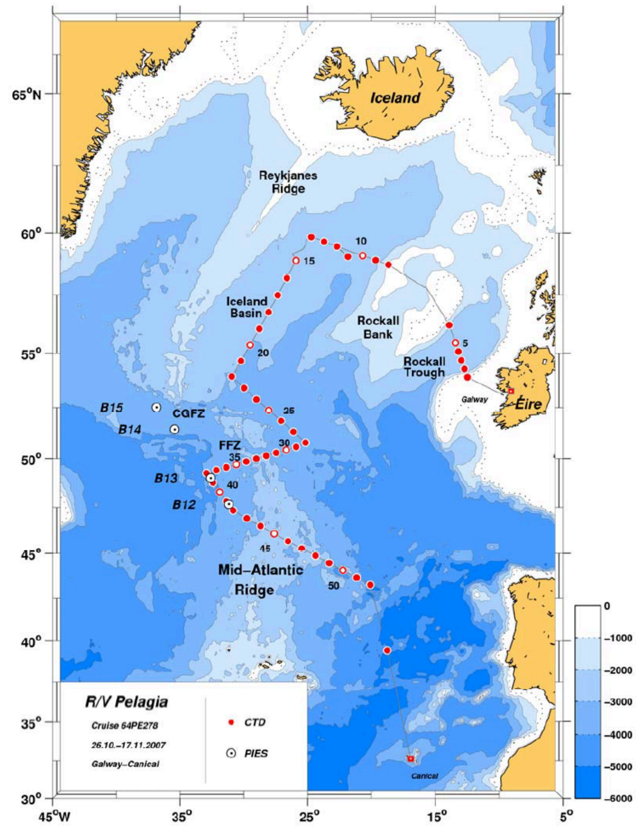
CRUISE REPORT: 64PE278

(Updated MAY 2020)



HIGHLIGHTS

Cruise Summary Information

Section Designation	**64PE278**
Expedition designation (ExpoCodes)	**64PE20071026**
Chief Scientists	**Dagmar Kieke / UNI-BREMEN**
Dates	2007 OCT 26 - 2007 NOV 17
Ship	RV *Pelagia*
Ports of call	Galway/Ireland to Caniçal, Madeira/Portugal
Geographic Boundaries	59° 49.89' N 32 57.01' W 12° 28.79' 39° 25.92'N
Stations	53 CTD Stations
Floats and drifters deployed	0
Moorings deployed or recovered	0

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Final report assembly by Jerry Kappa, SIO/UCSD

<u>Cruise Report</u>

RV Pelagia

leg 64PE278

- The „BREMEN Barter“ -

October 26th - November 17th 2007
From Galway/Ireland to Caniçal, Madeira/Portugal

by

Dagmar Kieke, chief scientist,

and

Maaike Claus, Sandra Erdmann, Madlen Gebler, Gerd Kunert, Harald Poigner, Patrick Schmidt, Reiner Steinfeldt, Uwe Stöber, Steven van Heuven, and Evaline van Weerlee

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Table of Contents

Aims of *Pelagia* cruise 64PE278

Physical Oceanography (Dagmar Kieke)

As part of a large-scale field survey, hydrographic casts shall be combined with measurements of anthropogenic tracers such as chlorofluorocarbon (CFC, components CFC-12 and CFC-11) as well as data recorded by moored inverted echo sounder equipped with a bottom pressure sensor (PIES) and profiling Argo-drifters. By combining theses data changes in the formation rate of Labrador Sea Water (LSW), changes in the water mass transformation as well as changes in the propagation of climate-signals across the subpolar North Atlantic shall be detected and related to variability in the strength of the subpolar gyre of the North Atlantic. Furthermore, work carried out on *R/V Pelagia* during cruise 64PE278 aims at providing answers whether a significant amount of Upper Labrador Sea Water (ULSW) has been formed in the Irminger Sea in winter 2007 or has been exported from the Labrador Sea. From April to June 2007, two different legs with *R/V Maria S. Merian* were undertaken that both covered the western part of the subpolar gyre (leg MSM-05/1, PI: M. Rhein, University of Bemen, Newfoundland Basin; leg MSM-05/2, PI: J. Fischer, IFM-GEOMAR Kiel, Labrador Sea). From these cruises a hydrographic and tracer data set is available for a large-scale investigation of water mass spreading. In September 2007, *R/V Pelagia* sailed from Greenland to Ireland in the framework of NIOZ-cruise 64PE275 (PI: G.-J. Brummer/H. van Aken). A team from the University of Groningen, led by S. van Heuven, provided another set of about 530 tracer samples which had been collected on behalf of the University of Bremen. In combination with data collected during cruise 64PE278 this data set will provide an important contribution for determining the chlorofluorocarbon inventories of North Atlantic Deep Water (NADW) components for the year 2007. The latter is important for estimating the total formation rate of ULSW in the period 2005-2007. Furthermore, this combined data set is suitable to track climate signals and analyse the basin-wide spreading of LSW. Measurements undertaken during cruise 64PE278 also serve to continue existing long-term time series of hydrographic and tracer properties of North Atlantic Deep Water components.

Marine Chemistry (Steven van Heuven)

During this cruise a study is made of how much of the atmospheric CO_2 that enters the ocean surface finds its way to deeper layers in the ocean. This is done through highly accurate analysis of the several hundreds of water samples that will be brought on board during the cruise. Analysis takes place in a dedicated laboratory on board. Therefore, data will be available for further analysis almost directly upon finishing the transect. Rather complicated calculations combining fundamental biogeochemical knowledge with extensive real-world datasets, as well as conceptually straightforward comparisons of the recent CO_2-system data with data from earlier coverage of the same ocean region, will yield improved and important understanding of the increase in ocean CO_2 content through the recent decades. This knowledge will prove highly valuable in predicting the ocean's potential for further uptake of anthropogenic CO_2, and its attenuating effect on global climate change.

Participating Research Programmes

(a) „*Verbundvorhaben Nordatlantik*" (Dagmar Kieke)

Cruise 64PE278, *R/V Pelagia*, was undertaken in the framework of the German project *Verbundvorhaben Nordatlantik*, Work Package 2.1, funded by the German Federal Ministry of Research and Education (*BMBF*).

The subpolar North Atlantic is a key region for the meridional overturning circulation (MOC). Here, different components of North Atlantic Deep Water (NADW) are formed that leave the subpolar North Atlantic on different pathways. The lightest contribution to the deep and cold MOC branch is termed Labrador Sea Water (LSW). It is formed by winter-time convection in the Labrador Sea. From its formation region it is injected into the Deep Western Boundary Current (DWBC), spreads into the Irminger Sea, and follows pathways across the Mid-Atlantic Ridge into the eastern basin of the subpolar North Atlantic.

Verbundvorhaben Nordatlantik is a German contribution to *CLIVAR (Climate Variability and Predictability)*. It aims at combining a broad variety of observational data and output from different kinds of general ocean circulation models. The final aim will be to develop components of a diagnosis and prediction system which allows detecting the influence of large-scale changes within the Atlantic sector on regional conditions in the European shelf area. For this reason, knowledge concerning the physical role of the North Atlantic with respect to transport of energy and substances (e.g. CO_2) within a changing global climate is necessary.

The aims of Work Package 2.1 are related to investigating the variability of transports of the North Atlantic Current (NAC) when it enters the subpolar Northeast Atlantic, thereby importing warm and saline waters of subtropical origin. Furthermore, the variability of formation of LSW shall be determined for the period 2005-2007. An investigation of large-scale changes of temperature and salinity as well as layer thickness within different types of LSW will be undertaken as well as detecting those density layers which are ventilated and renewed by winter-time convection in the Labrador Sea. Finally, an index representing the formation history of upper and deep LSW will be developed from combining hydrographic and tracer data.

(b) Dutch Contribution to *Carboocean* (Steven van Heuven)

The European Union-funded integrated project CARBOOCEAN consists of a rather large number of subprojects, with the overarching goal of gaining a better understanding of the oceanic contribution to the global carbon cycle, with an emphasis on the Atlantic Ocean. One of the main aims of the project is to better quantify the ocean's uptake of atmospheric carbon dioxide (CO_2), the most important manageable driving agent for climate change. The ocean is a highly significant sink for man-made (anthropogenic) CO_2. The correct quantification of this sink is a fundamental necessary condition for all realistic prognostic climate modelling.

1. Cruise Summary

1.1 Cruise Information

a:	**Expedition Designation (EXPOCODE):** 64PE278	
b:	**Chief Scientist:** Dr. Dagmar Kieke Institut für Umweltphysik (IUP) Universität Bremen Otto-Hahn-Allee 28359 Bremen Germany	Telephone: +49 421 218 4562 Telefax: +49 421 218 7018 email: dkieke@physik.uni-bremen.de URL: www.ocean.uni-bremen.de
c:	**Ship:** RV Pelagia **Call Sign:** PGRQ **Captain:** Mr. John C. Ellen **length:** 66 m **beam:** 12.8 m **draft:** 4 m **maximum speed:** 11 knots	
d:	**Ports of Call:** Galway/Ireland and Caniçal/Madeira/Portugal	
e:	**Cruise dates:** October 26th, 2007 to November 17th, 2007	

Figure 1.1: *R/V Pelagia while in Galway.*

1.2 Cruise Track and Station Operations

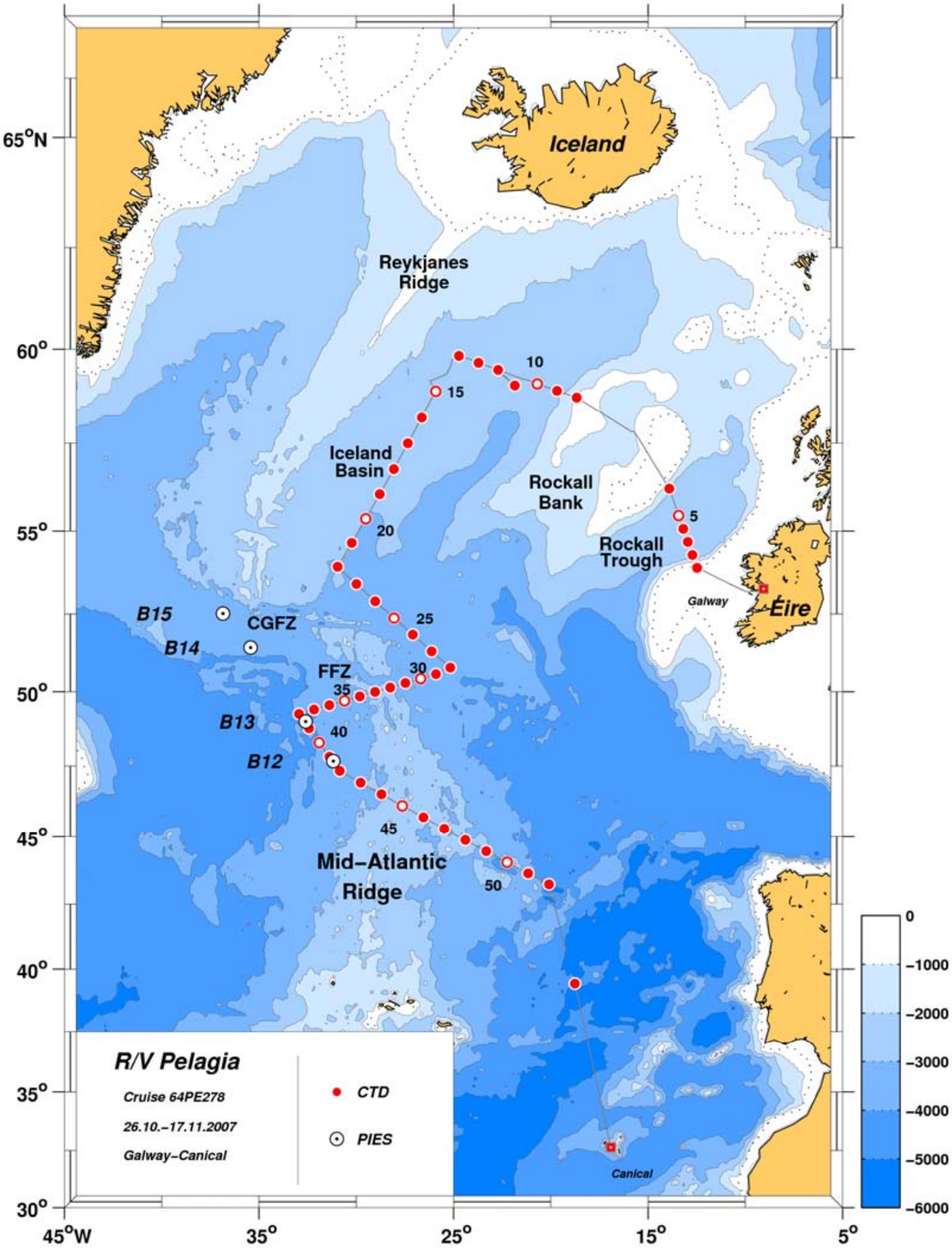

Figure 1.2: *Track of R/V Pelagia, cruise 64PE278. Every 5th profile is highlighted by its number. Bathymetric contours are shown every 1000m, stippled lines indicate the 500m-isobaths. Abbreviations are: CGFZ: Charlie-Gibbs-Fracture-Zone, FFZ: Faraday-Fracture-Zone, CTD: Conductivity-Temperature-Depth Measurements, PIES: pressure-inverted-echo-sounders.*

1.3 Cruise Track Description

The first set of seven stations followed a line crossing the Rockall Trough. Typical station distances were 25 nm. Station 6 was skipped due to instrumental failure (see Cruise Narrative). Having finished this hydrographic section, *R/V Pelagia* was on transit across the Rockall Bank into the Northern Iceland Basin. Here, stations 8-14 were carried out with station distances of about 27 nm. Very unfavourable weather conditions prevented *R/V Pelagia* from sailing into the Irminger Sea as was originally intended. Therefore, starting with profile 15, a section along the eastern side of the Reykjanes Ridge was undertaken that followed the spreading of Iceland-Scotland-Overflow Water (ISOW) in southwestern direction.

Due to the limited amount of time station spacing was increased to about 50 nm. Reaching station 22, course was changed to a southeastern direction. Thereby, *R/V Pelagia* followed a section along the eastern exit of the Charlie-Gibbs-Fracture-Zone (CGFZ) and Faraday-Fracture-Zone (FFZ), the main gateways for western North Atlantic Deep Water (NADW) components to enter the eastern subpolar basin. After finishing station 28, course was changed again towards west. Station spacing was decreased to 32 nm to allow for detection of NADW components flowing along the Mid-Atlantic Ridge.

Having finished station 38, *R/V Pelagia* turned towards southeast to undertake a section along a line of moored pressure-inverted-echo-sounders (PIES), deployed in 2006 by IUP, University of Bremen. Station distances were increased to 36 nm.

The final hydrographic section of cruise 64PE278 was directed towards southeast, thereby crossing the Mid-Atlantic Ridge once again but at a more southern latitude. Stations were up to 53 nm apart. Section work ended at station 52.

While already on transit towards Madeira, station 53 was carried out, which was undertaken as a CTD-only station to test scientific equipment.

1.4 Hydrographic Station Work

A total number of 53 vertical CTD/water sampler casts has been successfully carried out. With the exception of profile 6, which was entirely skipped, and test-station 53, sea water samples tapped from an SBE 32 carousel water sampler were taken at all remaining stations. Water samples were directly analysed with respect to salinity, oxygen, dissolved inorganic carbon (DIC), total alkalinity, as well as nutrients such as phosphate, nitrate+nitrite, and silicate. Further samples were taken and properly sealed for storage in order to analyse chlorofluorocarbon (CFC) concentrations in the CFC laboratory of IUP at the University of Bremen.

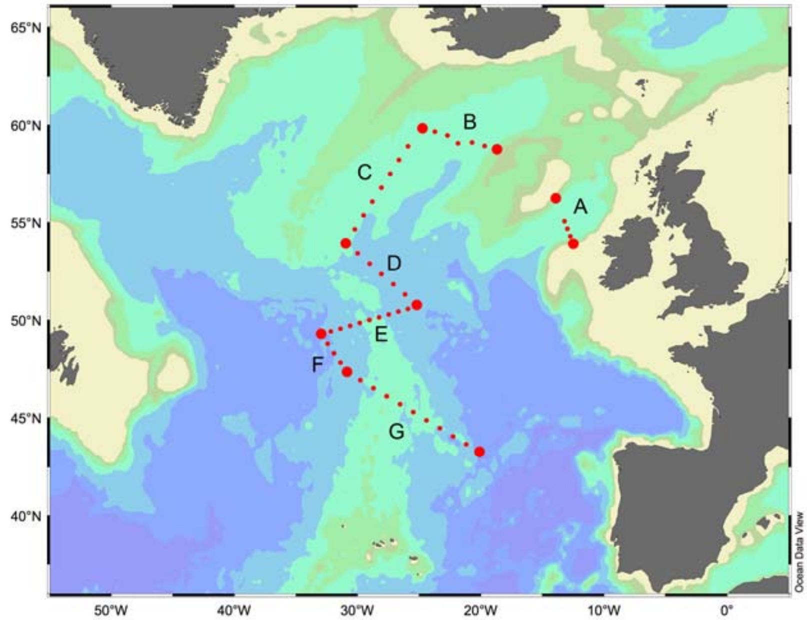

Figure 1.3: *Map indicating stations with available nutrient and carbon-related data. Letters A-G refer to sections shown in Chapter 4.*

1.5 Cruise Narrative

On October 26th *R/V Pelagia* left Galway at 15:00 UTC. Course was set to 270°, so we headed with 10 knots towards the continental shelf break and Rockall Trough where we expected to perform the first set of stations. The overall distance was about 170 nm. A test station was thought to be carried out the next morning soon after breakfast, the first 'real' profile was to be expected to be performed before noon.

On October 27th, 08:00 UTC, we reached the working area and began a test station at a water depth of 410m. While the recording of CTD data was successfully, the system failed in allowing closing water bottles. Therefore, it was not possible at this location to tap any sea water samples. While the CTD/water sampler system was heaved out of the water, the way doing so turned out to be problematic for the lowered ADCPs attached to the water sampler frame. The ship hull close to the A-frame on *Pelagia*'s starboard side is equipped with rubber fenders, and the deck crew is well experienced in securing CTD/water sampler systems directly against this protective rubber cover. It was therefore started to turn around the water sampler while still in water, before retrieving it back on. In doing so, the ADCPs could be prevented from touching the ship's side. With experiences from several German or French vessels, the habit of securing the CTD/water sampler system next to the ship's side was not known to the German scientific party.

Profile 1 was the first in a set of hydrographic profiles that followed a line in northwestern direction across the Rockall Trough. It was started at 09:20 UTC, almost immediately after the test station had been finished. Station work continued along this line until profile 5. On October 28th at 06:00 UTC this profile had to be aborted. While about 100m above the bottom, the CTD underwater unit owned by the University of Bremen did not respond correctly. Parameter values were far beyond the expected range. Restarting the data recording and the deck unit was not successful, since the underwater unit could not be contacted again. For this reason, the CTD/water sampler system was retrieved again and inspected in detail. Sample bottles could not be closed, and the up-cast-profile of this station was not available. Several checks indicated that the CTD-system had an electronic failure, and we had to switch to a second CTD-underwater unit, which we had taken with us as a spare instrument. While the inspection continued, *Pelagia* still sailed along the intended section, thereby skipping profile 6. At 14:40 UTC, profile 7 was undertaken at the western edge of the Rockall Trough section, close to Rockall Bank. The spare CTD underwater unit operated without the occurrence of problems.

Having finished the Rockall Trough section *Pelagia* was on transit across Rockall Bank. Originally, it was intended to carry out a section across the northern Iceland Basin at a latitude of about 59°12'N. Due to worsened weather conditions it was decided to carry out this section at a more southern latitude. Therefore, *Pelagia* changed from its northwesterly course towards a more westerly course and headed on at velocities of 6-7 knots. In the early morning hours of October 30th *Pelagia* reached the position of profile 8 which is located at the western flank of Rockall Bank. Water depth was about 770m, and no further instrumental problems were experienced. At profile 9, recorded salinity profiles showed peculiarities again. At a pressure of about 1300 dbar and more, the down-cast profile showed pronounced zigzags which covered a salinity range of about 7/100. In comparison to the up-cast profile a conductivity/salinity hysteresis was observed. This lasted on until the CTD/water sampler system was heaved back to pressures below 800dbar. Therefore, the salinity recorded at this station was not clearly definable. Having checked and cleaned cables and plugs once again, profile 10 started at 13:50 UTC the same day. Problematic salinity profiles were still recorded with large noise added to the actual signal. After communication with the technician at the home laboratory, a first suspicion appeared according to which a failure in the sea cable might be responsible for these erroneous CTD data. Similar experiences had been made earlier this year while on board *R/V Maria S. Merian*. The CTD-system was carefully checked once again and tested on the following day.

Starting at 08:00 UTC on October 31th a set of three test profiles was undertaken with different combinations of sensors, cables, and instrument connections. All tests failed, since erroneous data already showed up at pressures around 200-300 dbar. Communication with NIOZ (Bob Koster) brought up the idea and resulted in permission to use the NIOZ CTD/water sampler system to find out whether a problem with the conducting wire was present. In this case, this should show up also when using the NIOZ-system.

At 14:20 UTC the NIOZ-system was tested down to a pressure level of 500 dbar and was found to be working properly without showing the previously mentioned errors. All respective data were logged and later on sent by email to NIOZ. The NIOZ-system was detached from the conducting wire again, later on cleaned with fresh water and was no longer in use.

Communication with the home laboratory resulted in changing *Pelagia*'s course directly back towards Galway to have a technician and further spare parts flown in. On the way towards Galway another inspection of the Bremen system finally brought to light a short-cut in the cable which connects the pump to the CTD-underwater unit. The cable was replaced, and further improvements to the tygon tubings were made. At 18:30 UTC profile 11 started. Resulting data did not show any errors, so the system was found to be working properly. Since weather conditions close to Ireland worsened, *Pelagia* followed the previously intended section once again, and we refrained from picking up our technician at Galway. Therefore, *Pelagia* changed course to finish the hydrographic section across the northern Iceland Basin.

On November 1st profiles 12-14 were carried out. All respective data were properly recorded. At 16:40 UTC of the same day, the field program was interrupted due to worse weather conditions. While profile 14 still started at conditions good enough to deploy the water sampler system, conditions worsened throughout the time which made keeping the ship on position extremely difficult. While profile 14 was finished regularly, further station work was delayed until weather conditions improved to a more stable and suitable situation. Wind speeds in the late evening hours increased towards 9-10 Beaufort, occasionally reaching hurricane force. Due to the current weather situation and available regularly updated weather forecasts for the North Atlantic region, it was not possible to head into the Irminger

Sea. Trying to sail into this region would have cost too much valuable ship time, since several atmospheric lows were occupying this region. Respective weather forecasts predicted that they would stay for a longer time. As a consequence, the field program intended for the Irminger Sea was completely skipped, and one of the aims of cruise 64PE278, directly investigating ULSW formation in this particular area, could not be achieved.

Throughout November 2nd, weather conditions improved and allowed to continue station work which was resumed at 22:00 UTC. Profile 15 was started and regularly finished. On October 3rd, a failure in the network system of R/V *Pelagia* occurred which prevented the logging of underway measurements from 01:00 UTC until 17:00 UTC. Profiles 16 and 17 were finished along a southwestern route that approximately followed the course of the Reykjanes Ridge.

On November 4th, profiles 18 and 19 were conducted. Having finished profile 19, and while retrieving the CTD/water sampler system, a break in the aluminium frame of the water sampler was detected. This was probably caused while the frame was touching the ship's hull when securing the water sampler system at the ship's side. The frame was repaired with the help of the ship's engineers who temporarily attached metal angles next to the break in the frame in order to keep it in a stable position. At the end of the day, profile 21 started at 22:40 UTC. This was the last but one station along the Iceland Basin section.

On November 5th, profile 21 was finished in the early morning hours. Having finished profile 22, course was changed towards southeast to conduct a line of stations which are located close to the eastern exit of the Charlie-Gibbs- and Faraday-Fracture Zones. *Pelagia* followed this course until November 7th, when she reached station 28. Course was changed again towards the west. Profile 29 starting at 07:20 UTC was the first in a set of profiles that aimed at crossing the Mid-Atlantic Ridge at distances of about 32 nm.

Station work followed this section until November 9th, when station 38 was conducted. The subsequent profiles 39-42 carried out until November 10th followed a line of moored pressure-inverted-echo-sounders (PIES) deployed by the University of Bremen in summer 2006. These profiles will be later on used in combination with acoustic travel times recorded by the PIES to estimate changes in the strength of the North Atlantic Current when entering the eastern basin. Station work continued until November 14th. The locations of profiles 43-52 led *Pelagia* back across the Mid-Atlantic Ridge (MAR) into the eastern basin of the North Atlantic. Therefore, two crossings are available that allow for detection of LSW flowing along and/or across the MAR. On November 15th, a further test station was done in order to check the CTD underwater unit with its original set of sensors. This test was successful, and therefore, the scientific program conducted during cruise 64PE278 was finished. At 10:00 UTC *Pelagia* started its long transit towards Caniçal/Madeira, heading forwards at about 9.5 knots. She arrived in Caniçal at 08:00 UTC on November 17th.

1.6 List of Cruise Participants

Ship's crew:

Name	**Responsibility**
John C. Ellen	Captain
Jeroen van Kralingen	Chief Mate
Anne Eiling	Second Mate
Jaap Seepma	Chief Engineer
Marcel de Kleine	Second Engineer
Sjaak Maas	Ship's Technician
Roel van der Heide	Ship's Technician
José A. Israel Vitoria	Ship's Technician
Ger Vermeulen	Ship's Technician
Garl Mik	Cook

Scientific Crew:

Name	Responsibility	Affiliation
Kieke, Dagmar	chief scientist, data evaluation, CFC sampling, hydrowatch	IUP
Claus, Maaike	carbon analysis	RUG
Erdmann, Sandra	hydrowatch, CFC sampling	IUP
Gebler, Madlen	hydrowatch, CFC sampling	IUP
Kunert, Gerd	hydrowatch, CFC sampling	IUP
Poigner, Harald	hydrowatch, CFC sampling	IUP
Schmidt, Patrick	hydrowatch, CFC sampling	IUP
Steinfeldt, Reiner	salinometry, CTD data mangement, hydrowatch	IUP
Stöber, Uwe	lADCP data evaluation, CFC sampling, hydrowatch	IUP
van Heuven, Steven	carbon analysis	RUG
van Weerlee, Evaline	nutrients and oxygen sampling and analysis	NIOZ

IUP – Institut für Umweltphysik, Universität Bremen, Bremen, Germany

NIOZ – Royal Netherlands Institute for Sea Research, Texel, The Netherlands

RUG – University of Groningen, Groningen, The Netherlands

1.7 List of Principal Investigators

Name	**Responsibility**	**Affiliation**
Dagmar Kieke	physical oceanography (CTD, ADCP, CFCs)	IUP
Steven van Heuven	carbonate system, nutrient and oxygen analysis	RUG

IUP – Institut für Umweltphysik, Universität Bremen, Bremen, Germany

RUG – University of Groningen, Groningen, The Netherlands

2. Underway Measurements (Dagmar Kieke)

Recording of underway measurements during cruise 64PE278 was almost continuous. Around 01:00 *UTC on November 3rd a network failure occurred which caused a data gap (see Figure 2.1). After 17:00 UTC data logging was continued again.*

2.1 Navigation

Information concerning time, ship's position, speed over ground and course over ground for analysing underway measurements have been logged by the shipboard *Sercel* Differential GPS. Respective data are collected in time steps of 1 minute by the ABC-system installed on *R/V Pelagia* and stored in daily MS-Excel-sheets. Station positions and respective UTC-times relevant for processing CTD and lowered ADCP data have been taken from a *Furuno* GPS owned by the University of Bremen, which was attached close to the deployment position of the CTD/water sampler system.

2.2 Echo Sounding

An echo sounder operating at 3.5 kHz was used to determine water depths. Respective values were collected by the shipboard ABC-system and inserted as well into the daily MS-Excel-sheets. Reported depths are uncorrected water depths. The resulting time series of water depths quite often showed the occurrence of data spikes which remain to be removed at the home laboratory. While at station, corresponding water depths were recorded by the captain and mates at bridge and handed over to the scientific party.

2.3 Meteorological Data

Near-surface meteorological parameters like air temperature and pressure, humidity, relative wind velocity and direction as well as solar radiation were logged and provided via the shipboard ABC-system. Relative winds were converted into true winds using the ship's speed and course over ground.

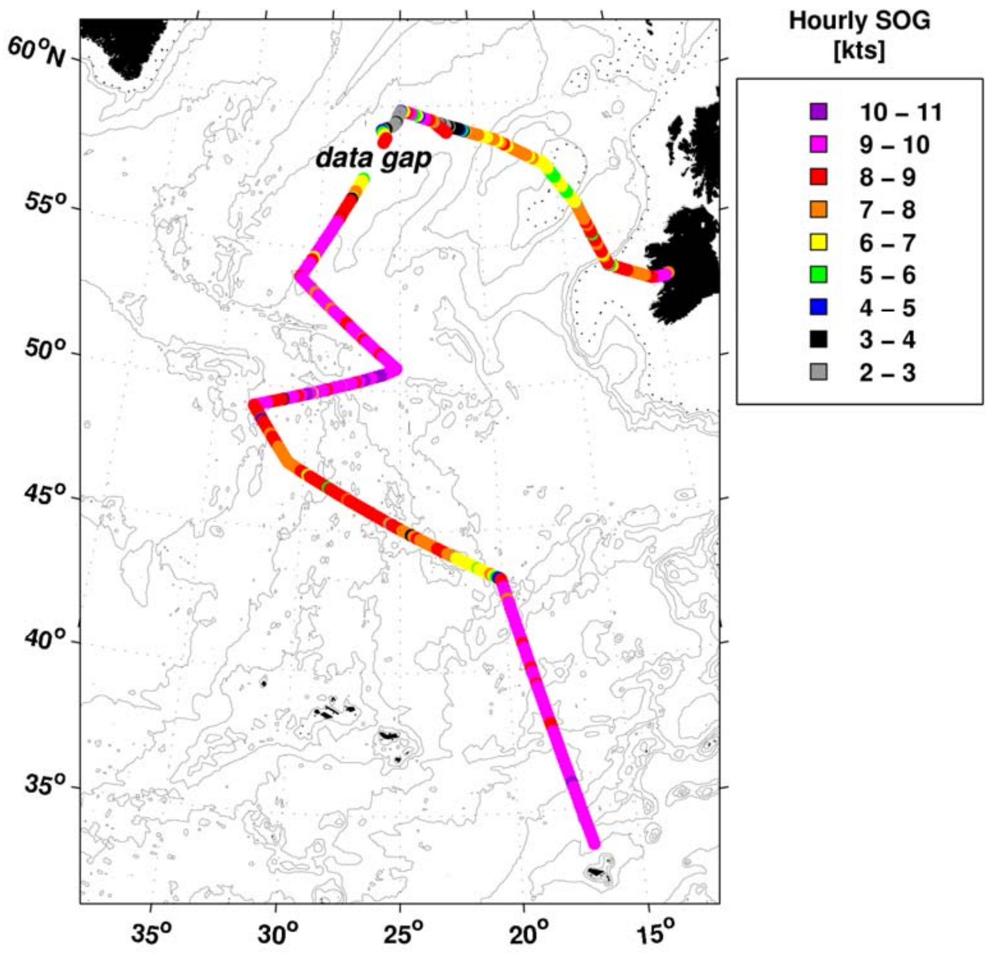

Figure 2.1: *Speed over ground [knots] during R/V Pelagia cruise 64PE278. Available data were averaged to hourly values. Values below 2 knots have been omitted to exclude station work. Bathymetric contours are shown every 1000m with stippled lines indicating the 500m-isobath.*

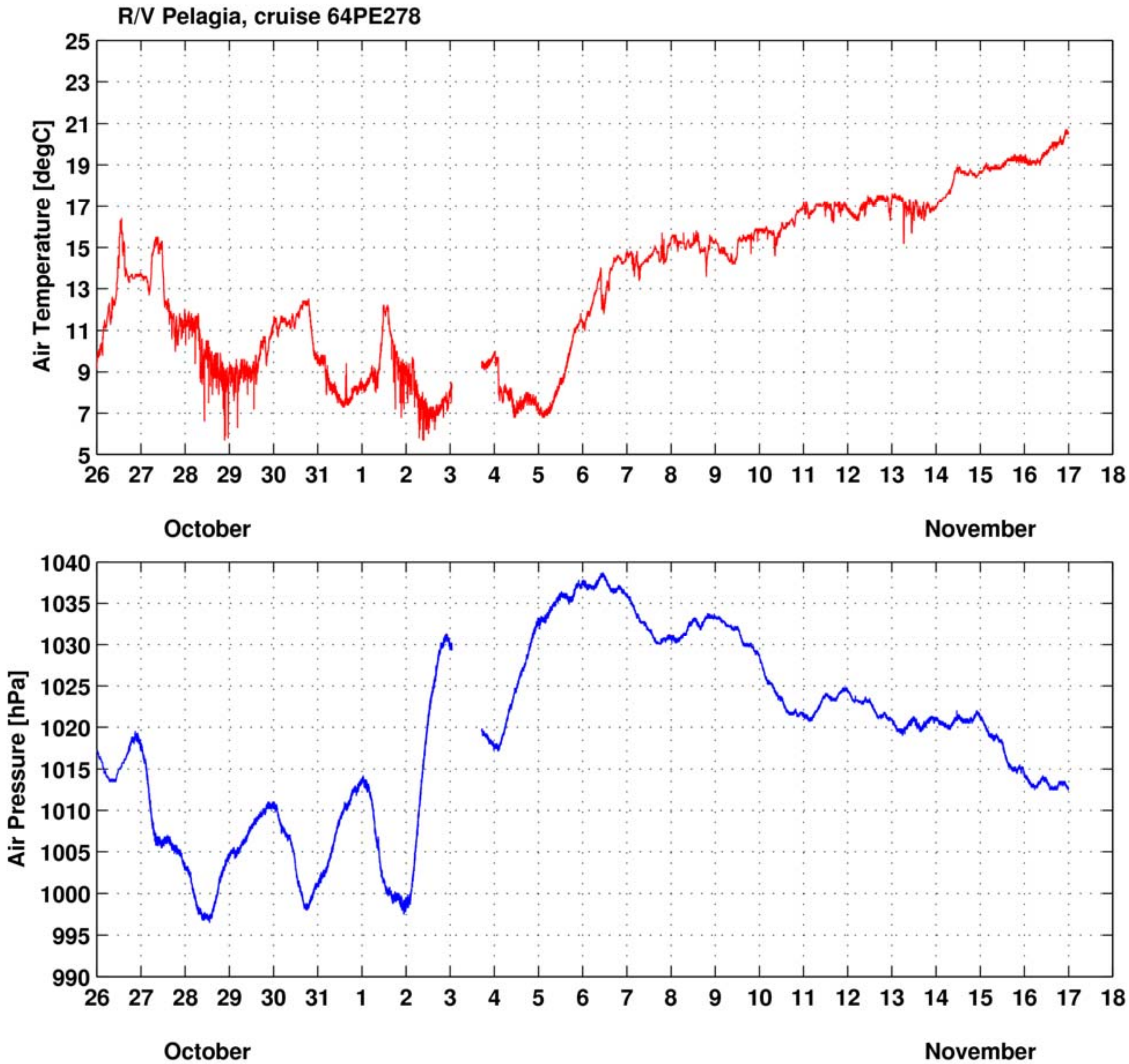

Figure 2.2: *Uncorrected air temperature (top) and air pressure (bottom) during October 26th to November 17th, 2007, as recorded minute-by-minute by the shipboard ABC-system.*

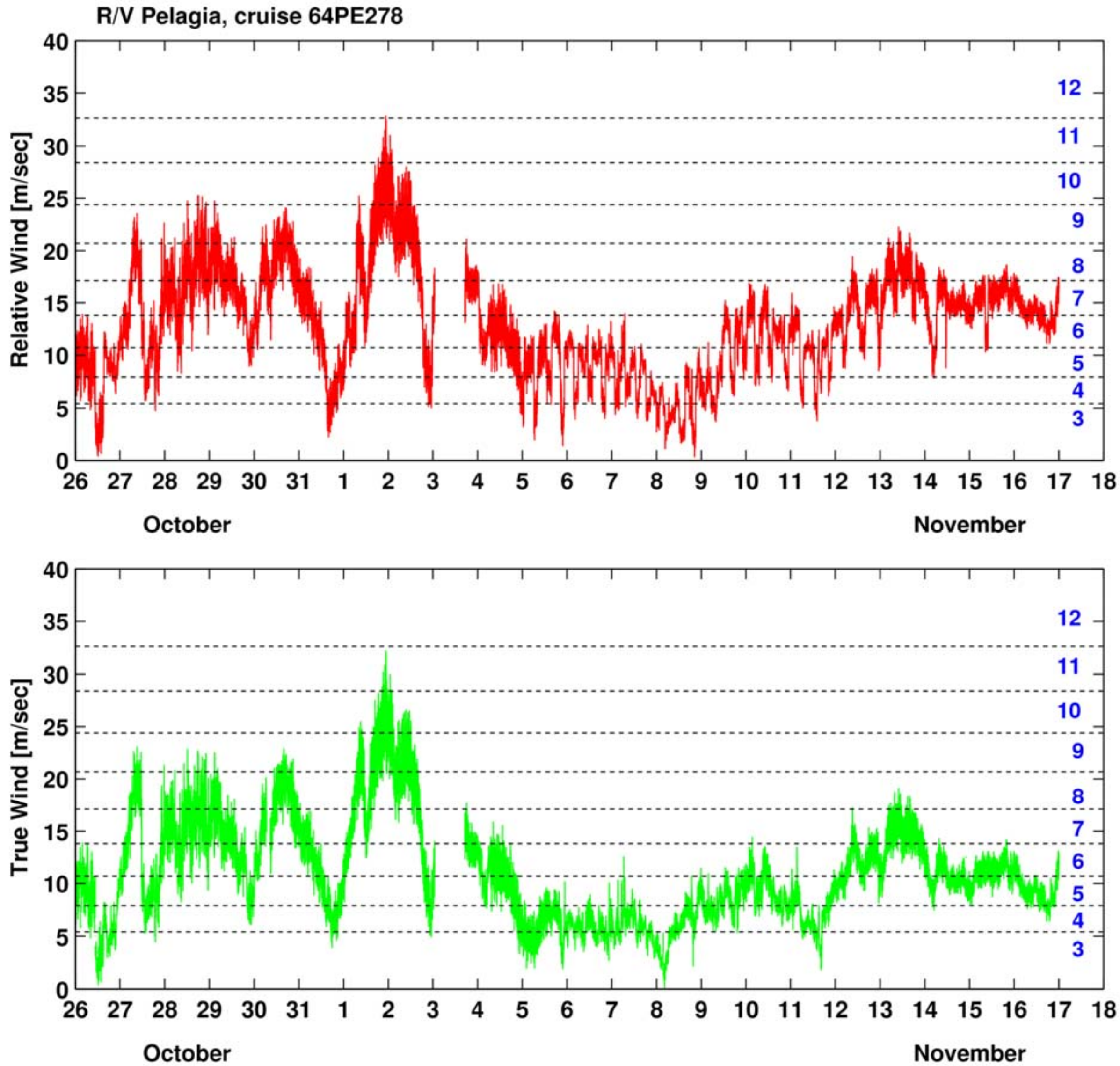

__Figure 2.3:__ Relative wind (top) during cruise 64PE278 as recorded minute-by-minute by the shipboard ABC-system and derived true wind (bottom). Units are in [m/s]. The Beaufort-scale from 3 to 12 is given to the right of each time series.

2.4 Thermosalinograph Measurements

Near-surface oceanic properties like sea surface temperature (SST), sea surface salinity (SSS), fluorescence and optical back-scatter were continuously recorded with the shipboard thermosalinograph system of type SBE-21 with the water intake at a depth of about 3 m. Measurements of fluorescence and optical backscatter were not of importance for the intended investigations. For this reason, they were disregarded. SST and SSS measurements will be compared to CTD measurements. Final processing of data will take place at University of Bremen.

3. Station Measurements – Descriptions, Techniques, and Calibrations

Measurements carried out during cruise 64PE278 were related to aspects of physical oceanography as well as marine chemistry.

3.1 CTD Data Collection/Processing and Salinity Measurements (Reiner Steinfeldt)

At the beginning of the cruise, a Sea-Bird SBE 911 plus system together with a SBE 43 dissolved oxygen sensor was used to measure temperature, conductivity, pressure, and oxygen. At profile 5, the system failed towards the end of the downcast, i.e. any signals from the underwater unit could not be received. The underwater unit was replaced with a substitute of the same type, but without oxygen sensor. At profiles 9 and 10 below a pressure of about 1000 dbar, a hysteresis between up- and down-cast profiles as well as large oscillations occurred. Both effects were more pronounced for conductivity than for temperature. A test of the CTD system was performed, where the conductivity began to oscillate directly from the beginning of the profile. A modification of the connections between the underwater unit and the sea cable as well as the sea cable and the deck unit did not show any improvement. Prior to profile 11, all sensors, the pump, and the electric cable between the pump and the main housing,, which showed an indication of water intrusion, were replaced. Also, the arrangement of the pump at the main housing of the CTD was modified. After these modifications the CTD system operated well. In order to test the pump and the sensors used for profiles 7-10, they were brought into operation again at profile 53 at the end of the cruise. The CTD system in this configuration worked properly down to a depth of about 2000 m, which was the deepest sampling level of this station.

The CTD underwater unit was connected to an SBE 32 carousel water sampler equipped with 22 10 l Niskin bottles. Two out of 24 bottles had been removed to allow attaching two lowered ADCPs to the water sampler frame. At the test station at the beginning of the cruise (profile 0), the bottles could not be released from the deck unit due to communication errors between the deck unit and the carousel water sampler, and at profiles 2 and 3, only 21 bottles could be closed. For the remaining profiles no further communication error between different system components occurred.

Salinity samples from the Niskin bottles were measured by means of a Guildline Autosal 8400A. The salinometer was standardized with IAPSO standard seawater batch P145. About 3 to 4 samples per profile were analysed. These samples were used to calibrate the CTD conductivity sensors. At profile 10, an increased number of 11 salinity samples was taken to allow for correcting an erroneous CTD conductivity measurement. During the last of 4 sessions, the salinometer was not stable, from time to time it measured too high salinities. These samples could not be used for calibration. As the mean deviation between the uncalibrated CTD and the bottle salinities was in the order of 0.001, this loss of calibration samples did not have any influence on the data quality.

In order to get realistic data for profiles 9 and 10, the up- and down-cast profiles were averaged and the resulting mean profiles were smoothed. The conductivity for profiles 9 and 10 was calibrated on the basis of the undisturbed profiles 7 and 8, which were measured with the same set of sensors. The rms difference of the bottle salinities analyzed with the salinometer and the CTD values from profiles 9 and 10 after processing is about 0.005 for the samples below 1000 dbar. This deviation is a measure for the amplitude of the salinity oscillations of profiles 9 and 10 remaining even after applying the smoothing routine.

Profile Number	**rms difference between calibrated CTD and bottle salinities**
1 to 5	below 0.002
7 to 8	0.01 (0.004 below 1000 dbar)
9 to 10	0.005 (below 1000 dbar)
11 to 52	below 0.003

Table 3.1: *Remaining rms difference between calibrated CTD and bottle salinities after data processing.*

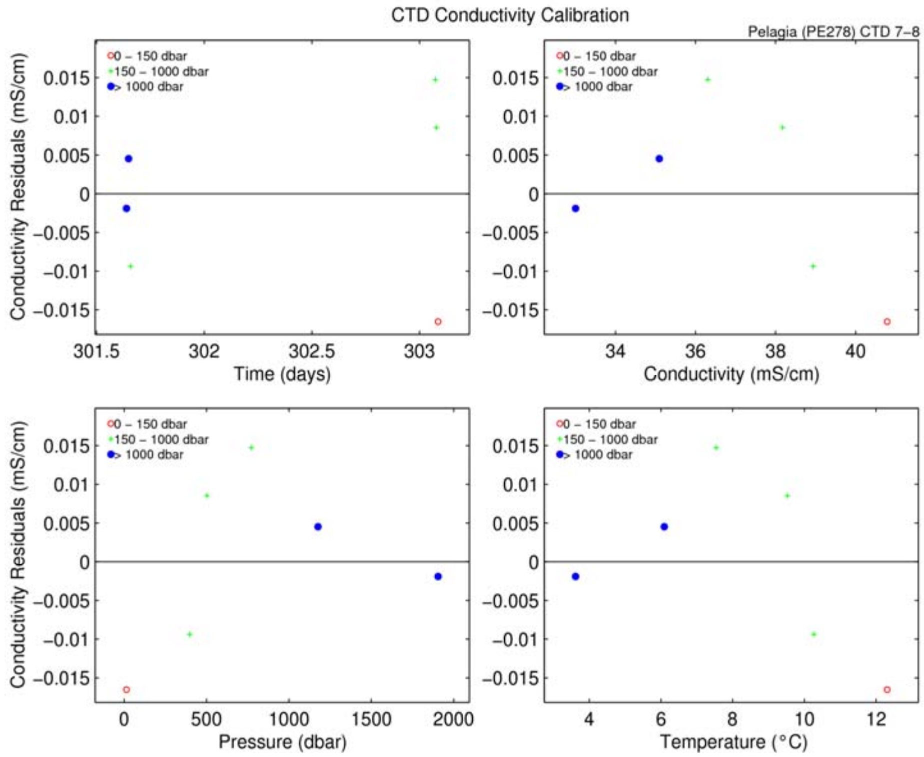

Figure 3.1: *Conductivity calibration of profiles 7-8.*

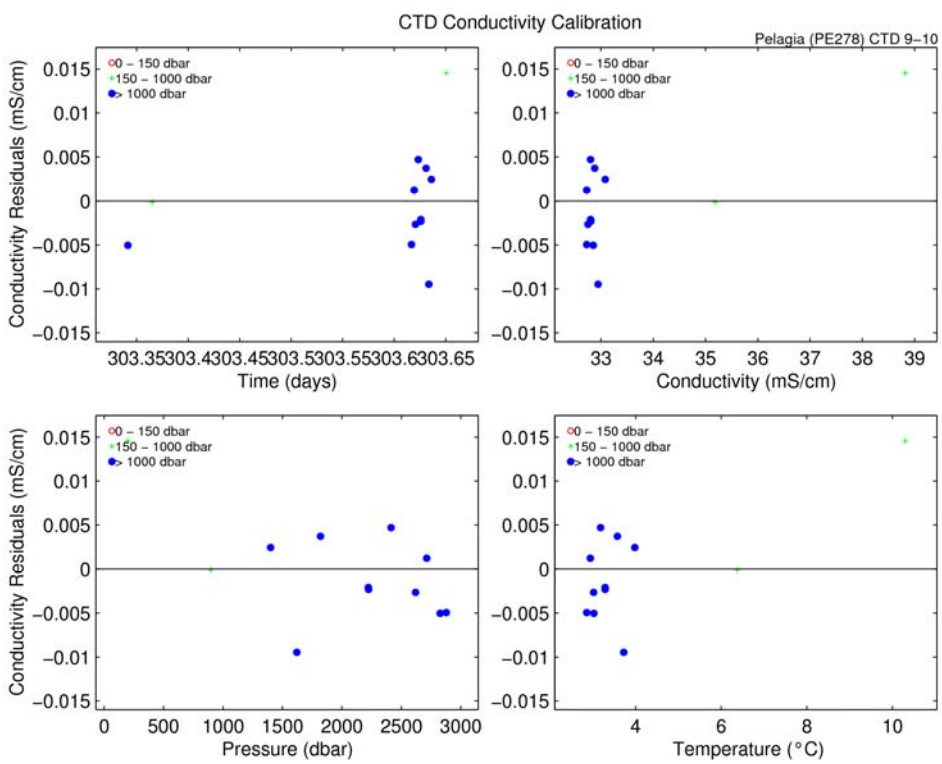

Figure 3.2: *Conductivity calibration of profiles 9-10.*

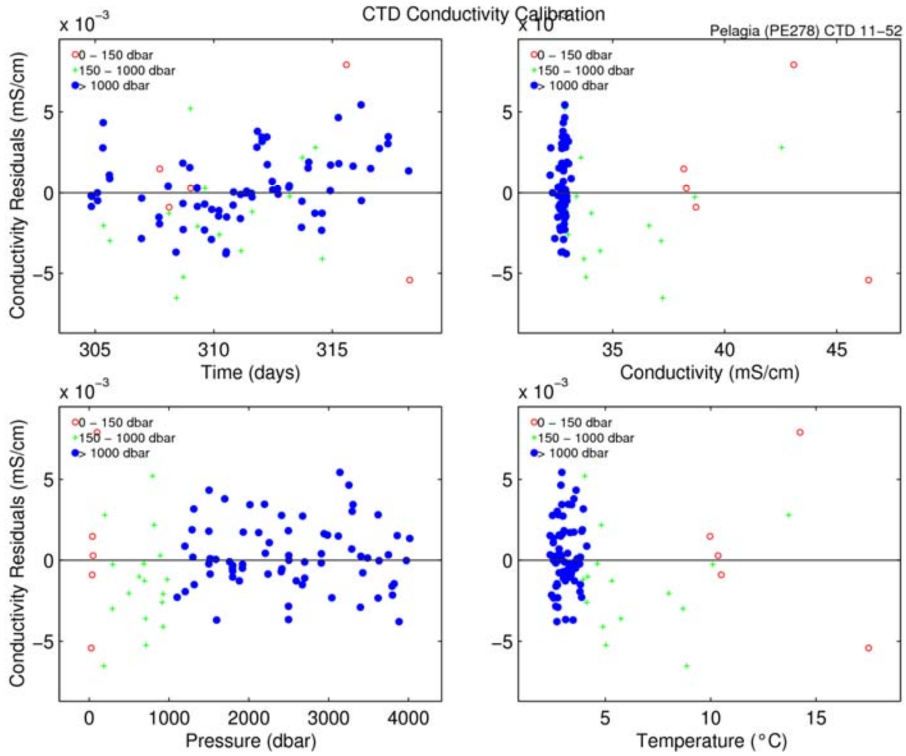

Figure 3.3: *Conductivity calibration of profiles 11-52.*

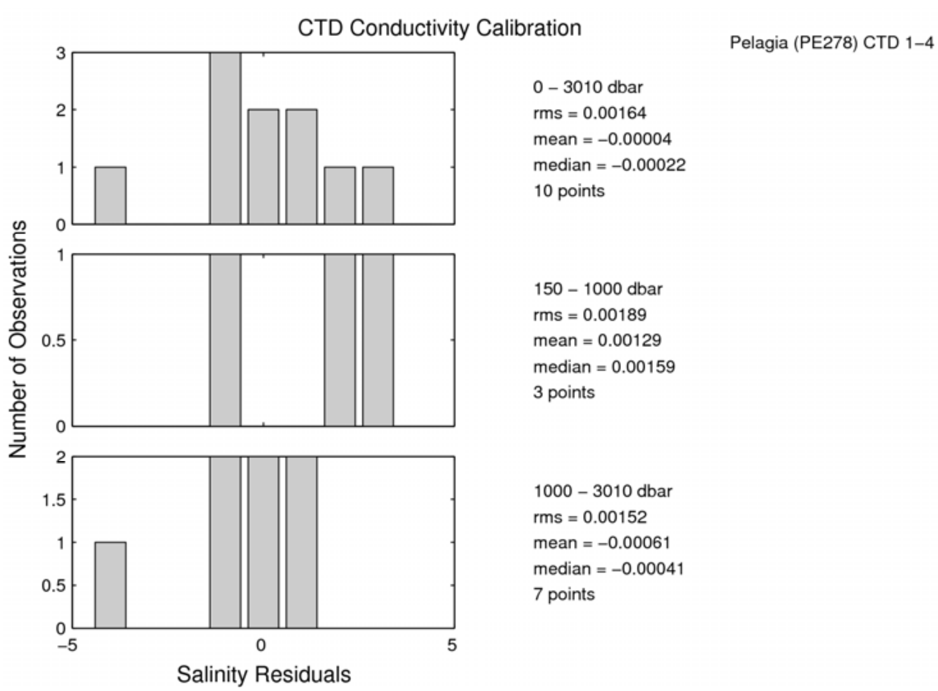

Figure 3.4: *Histogram of calibration results related to profiles 1-4.*

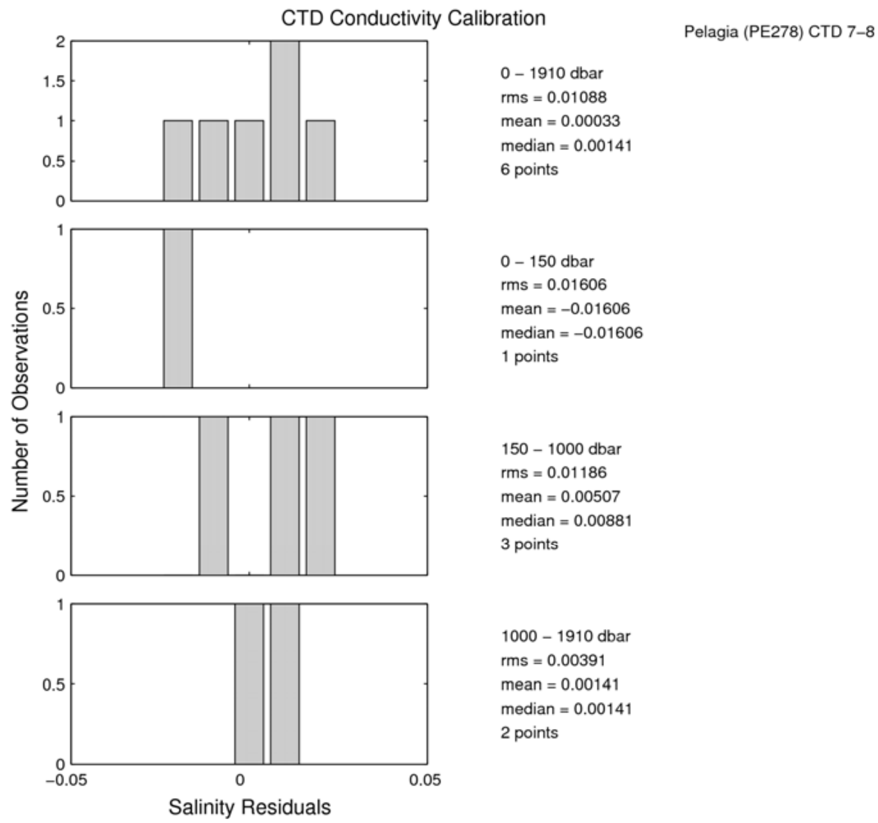

Figure 3.5: *Histogram of calibration results related to profiles 7-8.*

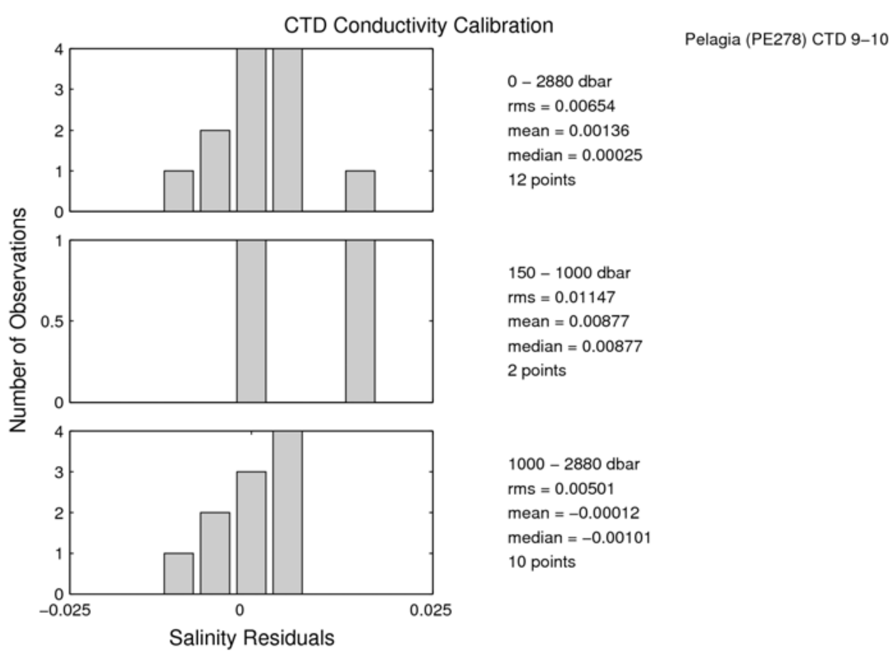

Figure 3.6: *Histogram of calibration results related to profiles 9-10.*

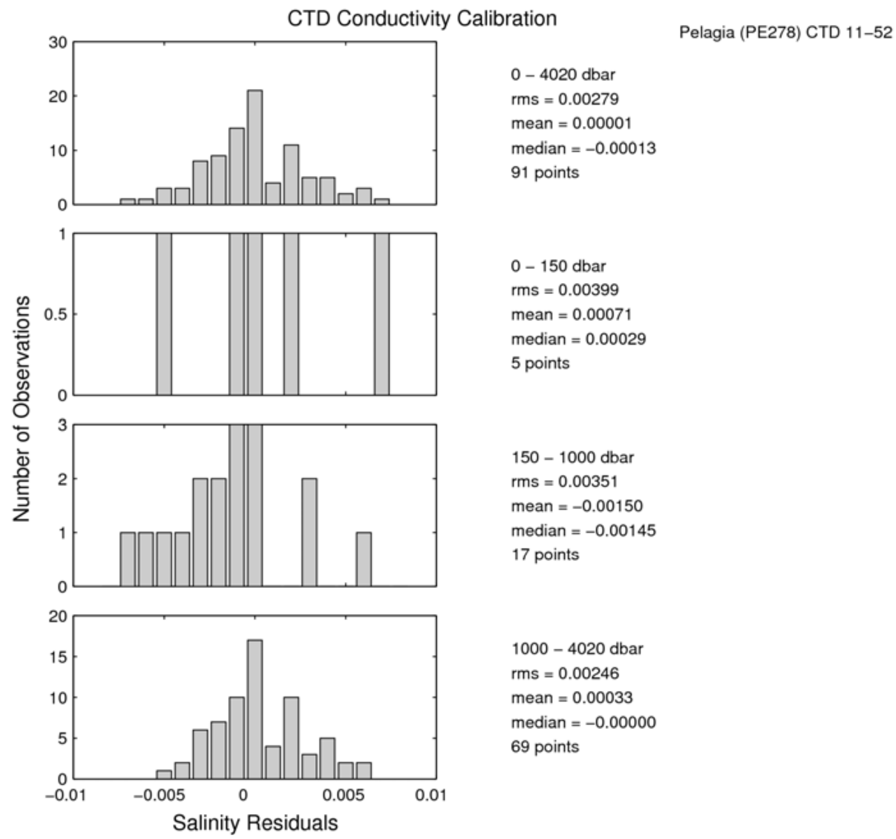

Figure 3.6: *Histogram of calibration results related to profiles 11-52.*

3.2 Lowered ADCP Data Collection and Processing (Uwe Stöber)

Two RDI Workhorse Monitor ADCPs with a frequency of 300 kHz were mounted to the carousel water sampler. The system was operated in a synchronized *Master-and-Slave* mode, with the *Master* looking in downward direction and the *Slave* looking in upward direction. For self-contained operation the instruments were powered by an external battery supply consisting of 35 commercial quality 1.5V batteries stored in an Aanderaa pressure housing.

The compasses of both instruments were calibrated prior to the cruise at shore in Galway to avoid perturbation of the Earth's magnetic field by the ship. The total error after calibration was 2.8° for the *Master* and 1.0° for the *Slave*. The system was set to a ping rate of 1 Hz and a bin length of 10m.

In total, 52 LADCP profiles were occupied during the cruise. Although compensator springs attached to the A-frame reduced the effect of any movements of the ship on the sea cable, intensive roll motions caused strong vertical accelerations of the instrument package. Figure 3.7 shows the vertical velocity of profile 2 suffering from the ship's roll motions. For comparison the figure also shows the vertical velocity during profile 27, which was recorded when weather conditions had improved. For both profiles the nominal lowering and heaving velocity was 1 m/s. Due to the vertical accelerations it was not possible to determine depth from integration of vertical velocity. Especially for profiles 1 to 5, 10, and 21 depth from integration of vertical velocity showed biases of up to 10% of the total profile depths. Therefore, depth calculated from the CTD pressure measurements had to be assigned to the ADCP raw data sets. Except for profiles 1 and 5, where the pressure data could not be fitted to the vertical velocity measurements of the LADCP, all profiles were processed using both depth from integration of vertical velocity and depth from CTD pressure.

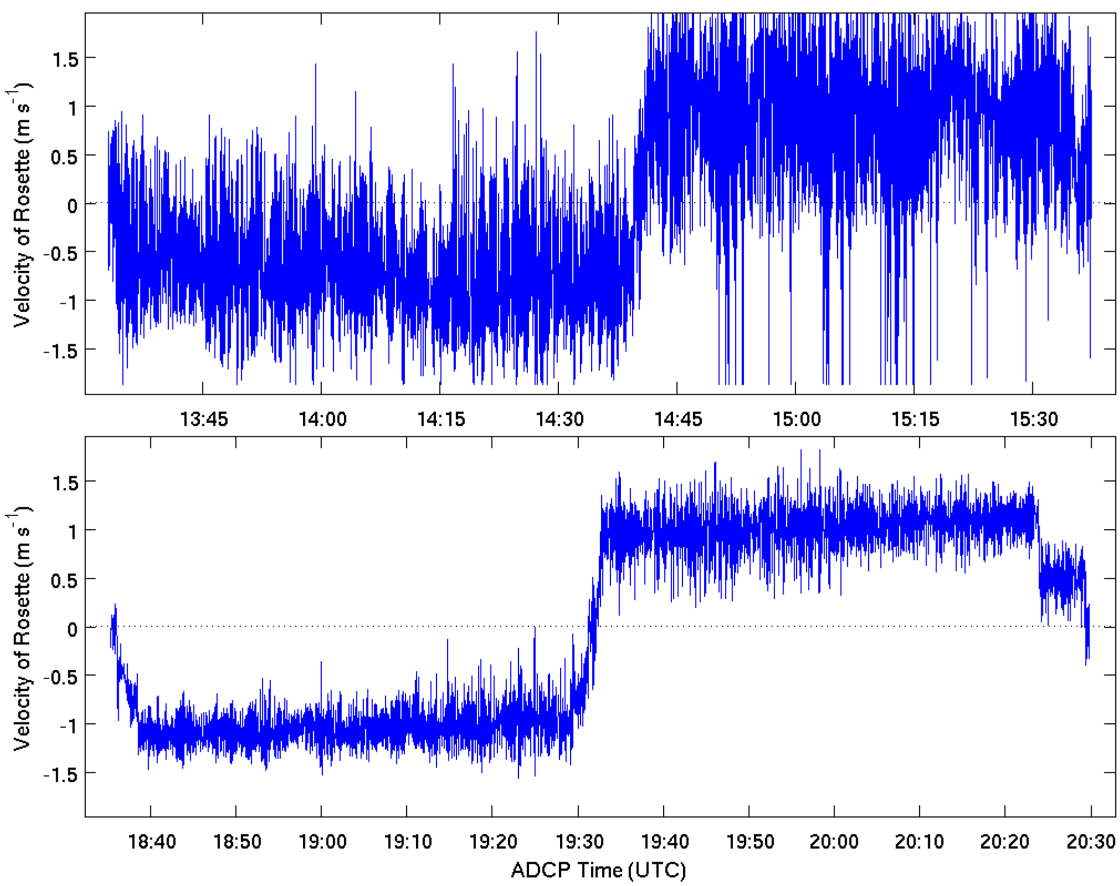

Figure 3.7: *Vertical velocity of the instrument package during profile 2 (top) and 27 (bottom). Compensator springs were active during both profiles.*

The range of a single instrument was up to 150m in shallow water and decreased down to 50m at large depth, i.e. the instrument package had a total range between 100m and 300m. With lowering and heaving velocities of no more than 1 m/s the number of shear estimates was thus usually above 200 at depth and reached typical numbers between 400 to 600 in the upper part of the water column with peak values of up to 800 in some profiles.

Despite the abundance of data, an inverse method which directly uses the velocity measurements did not show satisfying results during processing of profiles 1 to 23. In contrast, the traditional forward method based on shear worked well, probably because it reacts less sensitive to the strong motions of the instrument package. During the second half of the cruise when weather conditions were better and admitted profiles with less vertical motions of the instrument package, the inverse method seemed more appropriate and was applied to profiles 24 to 52. The quality of profiles 1 and 5 was non-sufficient due to the before mentioned low-quality depth estimates; profile 6 was completely canceled due to CTD failure. Thus, processing with the shear method and pressure from CTD data yielded 20 high-quality velocity profiles, while 29 profiles of as high-quality were obtained from the inverse method combined with CTD pressure, which gives a total of 49 profiles.

3.3 CFC Sampling (Dagmar Kieke)

A total amount of 1003 glass ampoules was filled with seawater collected at all water depths, from top to bottom. These samples will allow the analysis with respect to anthropogenic chlorofluorocarbon (CFC) concentrations at the Bremen home laboratory. Special focus is on the CFC components CFC-12 and CFC-11.

Seawater samples were taken using a carousel water sampler that carried a Seabird CTD/O_2 system as well as 22 Niskin bottles, all at 10 liters. Water samples necessary for CFC analysis were taken using so-called flow-through containers. These consist of a glass ampoule (volume of ~90 ml) which is connected to a head carrying a movable central and a fixed side tubing. These containers were attached to the Niskin bottles. Tapping and flushing of the CFC samples was carefully carried out without any contact to the atmosphere since diligent work is necessary to prevent any contamination of the water sample with CFC in gaseous air. After the entire filling of the containers was finished they were detached from the Niskin bottles and flame-sealed later on. In doing so, purified CFC-free nitrogen was inserted into the glass ampoule. By this means a head space was built up in the interior of the glass ampoule, i.e., a certain gas space is left in the ampoule which is necessary to accommodate the thermal expansion of the included seawater sample.

The glass ampoules were sealed by closing the open end of the ampoule with a burner fueled with propane gas. After the flame-sealing processes was finished and time for cooling of the sealed glass was allowed the remaining glass pieces were stuck on the labeled glass ampoule. Together with the precise dead weight of the glass ampoule which was carefully determined earlier in the Bremen laboratory, knowledge of the total weight of the flame-sealed glass ampoule is necessary for determining CFC concentrations later on.

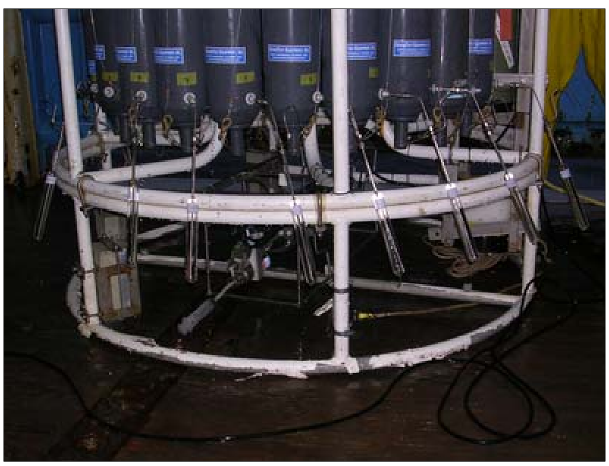

Figure 3.2a: *CFC sampling containers attached to the carousel water sampler (Foto by U. Stöber).*

Figure 3.2b: *Sealing CFC sample ampoules (Foto by D. Kieke).*

CFC-samples from profile 5 are missing due to an electronic failure in the CTD underwater unit which prevented closing the bottles. Despite profile 6 which could not be sampled at all and profile 53 which served as a CTD-only test station, water samples were taken at all other available hydrographic stations. At each station up to 23 flow-through containers were filled which results in a typical sampling level distance of 100-200m. In general, sampling depths were chosen to cover the entire water column from top to bottom. Special focus was on covering the water layers usually occupied by different types of Labrador Sea Water (LSW).

At the end of the cruise all samples will be shipped back immediately to the CFC laboratory for further analysis. The analysis in the home laboratory will follow procedures described by *Bullister and Weiss* [1988] and *Bulsiewicz et al.* [1998]. Out of 1003 samples, 8% have been taken as double samples to verify the reproducibility of the analysis.

References:

Bullister, J. L. and R. F. Weiss (1988), Determination of CCl3F and CCl2F2 in seawater and air, *Deep-Sea Res.*, 35, 839-853.

Bulsiewicz, K., H. Rose, O. Klatt, A. Putzka, and W. Roether (1998), A capillary-column chromatographic system for efficient chlorofluorocarbon measurements in ocean waters, *J. Geophys. Res.*, 103(C8), 15,959-15,970.

3.4 Dissolved Oxygen Measurements (Evaline van Weerlee)

Due to the limited oxygen analysis capacity available during the expedition, it was envisioned that chemical O_2-measurements were to be carried out only to serve as a calibration for the CTD-mounted oxygen sensor. Upon the early loss of availability of this 'CTDO-sensor' due to technical difficulties (after station 4), it was decided to postpone the O_2-calibration sampling until the sensor would be available again. When it became clear, however, that it would not likely become feasible to use the sensor, a very limited number of casts were sampled at full resolution for chemical O_2-measurements. The total number of analyzed samples is ~90, divided over 3 full-resolution stations and 4 limited-resolution (CTDO-calibration) stations.

For the determination of dissolved oxygen concentration, water samples were drawn into pre-calibrated

120 ml pyrex glass bottles. Before drawing the sample, each bottle was flushed with at least 3 times its volume. The determination of the volumetric dissolved oxygen concentration of water samples was carried out by measuring the formed Iodine colour at 460nm on a Traacs 800 continuous flow spectro-photometer, combined with a stand-alone NIOZ-made sampler, based on the Winkler technique (see Su-Chen Pai et al., Marine Chemistry 41 (1993), 343-351). A stock solution of KIO_3 was used in the analysis spiked seawater blanks (reversed order addition of the Winkler chemicals) to obtain a calibration line for calibration of the spectrophotometer.

3.5 DIC and Total Alkalinity (Steven van Heuven, Maaike Claus)

Circa 850 seawater subsamples of 0.6 L were collected from the Niskin bottles at different depths and analyzed (unpoisoned) within 1-12 hours after sampling for dissolved inorganic carbon and total alkalinity using a VINDTA-3C system (designed and built by Dr. L. Mintrop, Marine Analytics and Data, Germany).

Dissolved inorganic carbon (TCO_2) was determined by coulometry from a 20 ml subsample, following the method developed by Kenneth Johnson (Marine Chemistry, 1981). An automated extraction line takes a volumetric subsample, which is subsequently acidified with 8.5% phosphoric acid (H_3PO_4) to decrease the pH and convert all DIC to CO_{2aq}. The gaseous CO_2 is stripped from solution using nitrogen gas and the carrier gas is led into a coulometric titration cell. The titration current (required to electrochemically maintain the optical transmission of the coulometric solution, which is increased by the pulse of CO_2 being bubbled through it) is integrated over the duration of the titration and from that the concentration of DIC is calculated.

Total alkalinity (or 'titration alkalinity') was determined by potentiometric titration of 100 ml samples with 0.1 M HCl. From the titration curve the total alkalinity (TA) was calculated using a curve fit function, quite analogous to the modified Gran procedure.
The precision of both TA and TCO_2 was determined from duplicate analysis on a number of samples. The accuracy was set several times per day by running certified standards made available by Dr. A. Dickson of the Scripps Institution of Oceanography (USA).

3.6 Nutrients Measurements (Evaline van Weerlee)

From Rosette bottles 1005 samples were drawn for the shipboard determination of the 3 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 with an autoanalyzer based on colorimetry using a BRAN&LUEBBE QUAATRO autoanalyzer. The samples, taken from the refrigerator, were directly poured in open polyethylene vials (6ml) and put in the auto sampler-trays. The different nutrients were measured colorimetrically as described by Grashoff (1983).

- Silicate reacts with ammoniummolybdate to a yellow complex, which, after reduction with ascorbic acid forms a blue silica-molybdenum complex that 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 a blue complex and measured at 880nm.

- NO3+NO2: Nitrate was mixed with the buffer imidazole at pH 7.5 and reduced to nitrite by a copper-coated cadmium coil (efficiency > 98%), and measured as nitrite. Nitrite was diazotated with sulphanilamide and naftylethylenediamine to a pink coloured complex and measured at 550nm. The reduction efficiency of the cadmium column was measured in each run.

Calibration standards were prepared by diluting stock solutions of each nutrient 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 day. Each run of the system had a correlation coefficient for the standards of at least 0.999. The samples were measured from the surface to the bottom to obtain 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, the so-called nutrient-cocktail, was measured, as well as control standards sterilised in an autoclave or gamma radiation. These standards were used to check the performance of the analysis.

4. Preliminary Results

At the end of the cruise the resulting CTD data as well as hydrographic information stored in the bottle file was calibrated. Besides oxygen recorded by the CTD/O-sensor, these respective data are considered final.

4.1 Hydrography

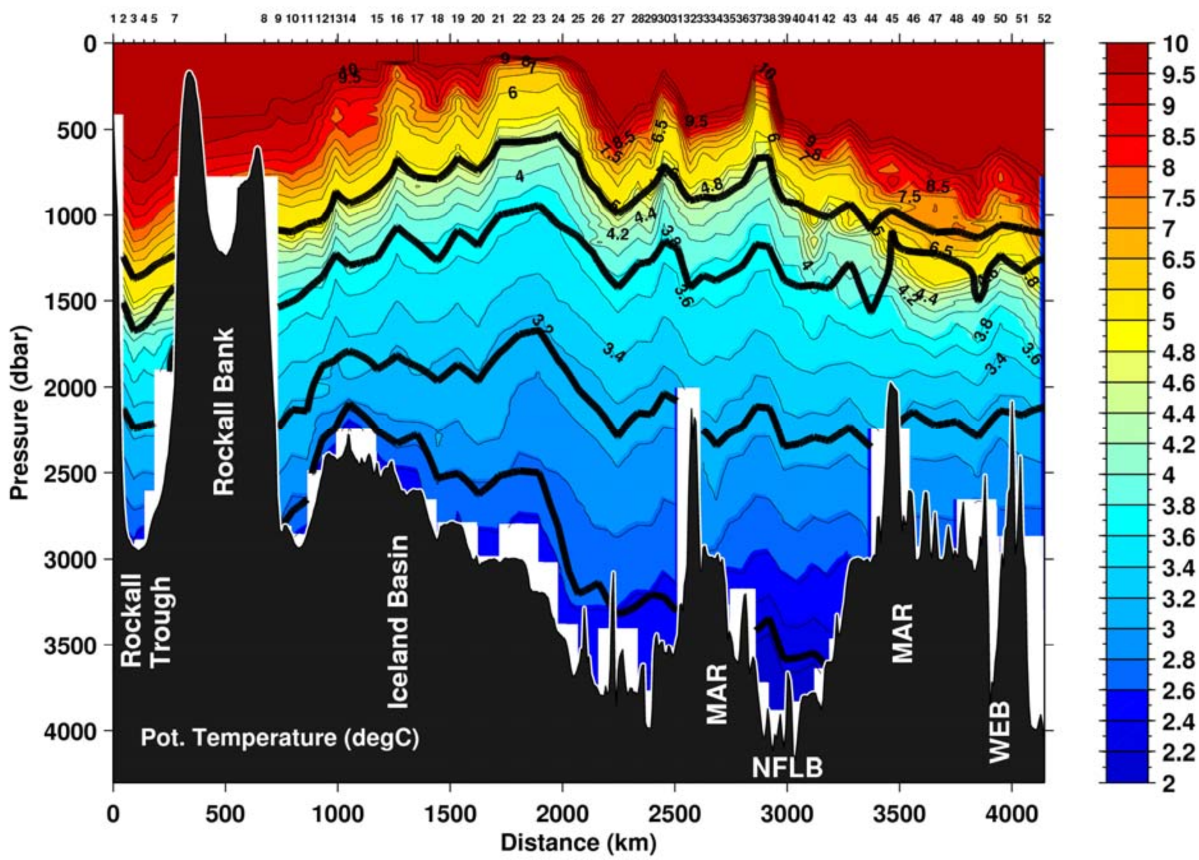

Figure 4.1: *Potential Temperature (°C) as recorded during CTD casts. The displayed section follows the cruise track. Noted abbreviations are: MAR – Mid-Atlantic Ridge, NFLB – Newfoundland Basin, WEB – West European Basin. Solid black lines indicate the isopycnals* σ_θ *= [27.68, 27.74, 27.80, 27.88] kg/m*^{3}.

Along the cruise track the lowest temperature at the shallowest water depths showed up at profiles 22-24 (see Figure 4.1). These stations are located at the eastern exit of the Charlie-Gibbs-Fracture Zone, the main gateway for water masses of western origin to pass towards the eastern basin. The upper limit of Upper Labrador Sea Water (ULSW), which is defined here in the density range σ_θ = 27.68-27.74 kg/m^3, is found at about 500 dbar. This is the only region observed during cruise 64PE278 where it is found at rather shallow depths. This is also the region where the freshest LSW was detected. The center of the minimum with a salinity below 34.91 was located at the isopycnal σ_θ = 27.74 kg/m^3. Deeper, within the layer of the so-called deep LSW (σ_θ = 27.74-27.80 kg/m^3) a local salinity maximum was observed. Since deep LSW is known for having a salinity minimum, this becomes more and more less pronounced, since in recent years this water mass was not ventilated any more. In contrast, local salinity maxima increasingly show up.

The final set of stations (45-52) undertaken in the West European Basin indicates the influence of Mediterranean Overflow Water, with a salinity well above 35.1 intruding into the deep LSW layer. At greater depths, there is still a detectable and pronounced salinity minimum which is centered at σ_θ = 27.78 kg/m^3.

The coldest bottom water was found in the Newfoundland Basin with temperatures below 2.2°C. The local bottom layer in this area is highly influenced by the presence of Denmark Strait Overflow Water with admixtures of remainders from Antarctic Bottom Water.

The purest Iceland-Scotland-Overflow Water (ISOW) becomes obvious at profiles 8-30. Here, a cold and saline bottom layer leans against the Reykjanes Ridge. It shows the highest salinity at profiles 11-17 in the northern Iceland Basin. There, ISOW spills across the Iceland-Scotland-Ridge which separates the deep subpolar North Atlantic from the Nordic Seas. Due to its high density it follows the topographic slope and shifts towards the sea bottom.

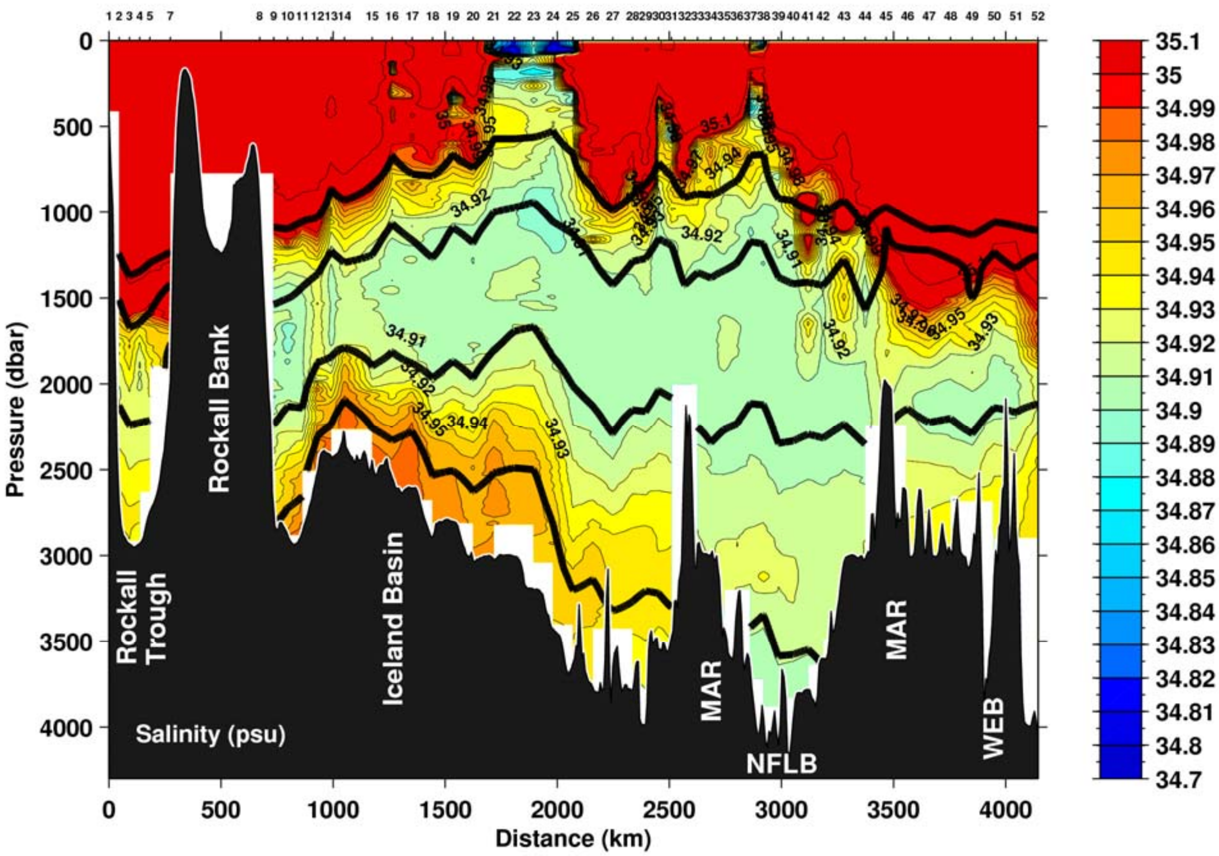

Figure 4.2: *Salinity distribution as recorded by CTD casts. Solid black lines indicate the isopycnals σ_θ = [27.68, 27.74, 27.80, 27.88] kg/m^3.*

4.2 Dissolved Inorganic Carbon and Total Alkalinity

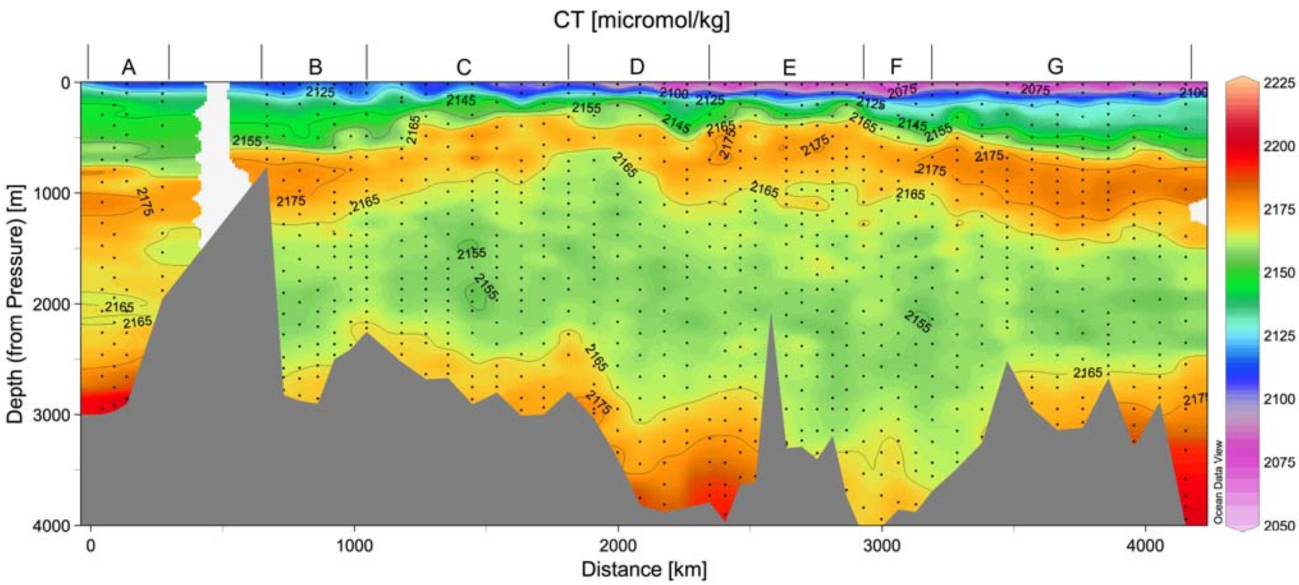

Figure 4.3: *Bottle-derived dissolved inorganic carbon (CT). Please note that these data have not yet been fully processed, and the figures derived from them may feature certain small anomalies and offsets. Letters A-G refer to the sections as indicated in Figure 1.3*

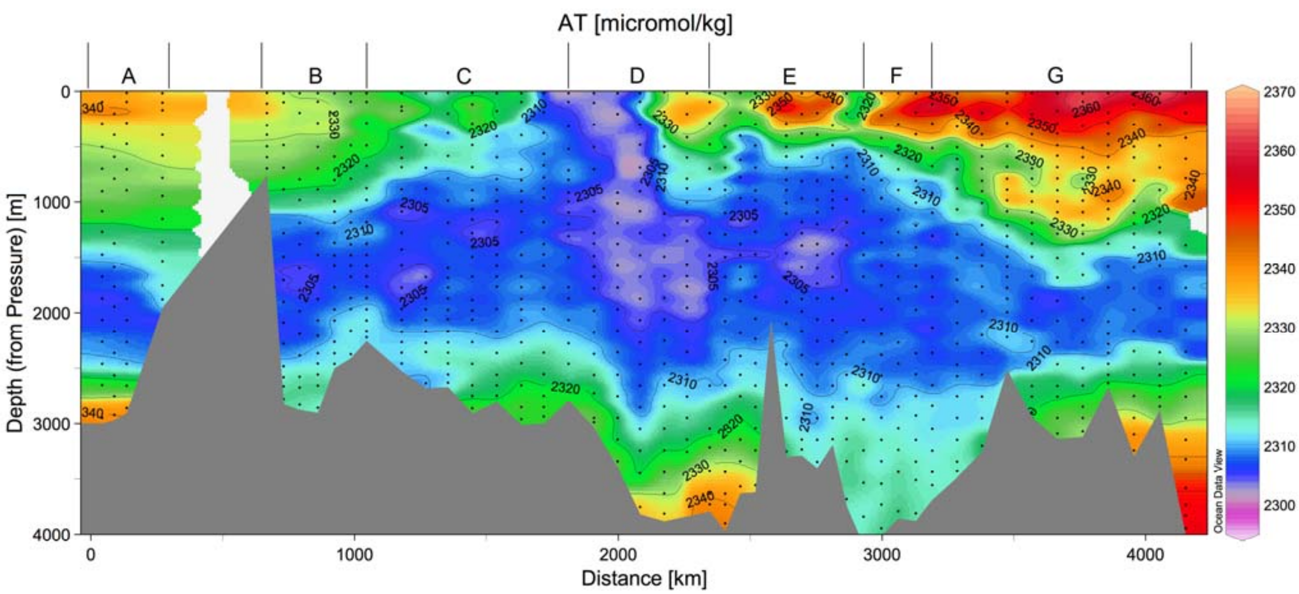

Figure 4.4: *Bottle-derived total alkalinity (AT). Please note that these data have not yet been fully processed, and the figures derived from them may feature certain small anomalies and offsets.*

4.3 Nutrients

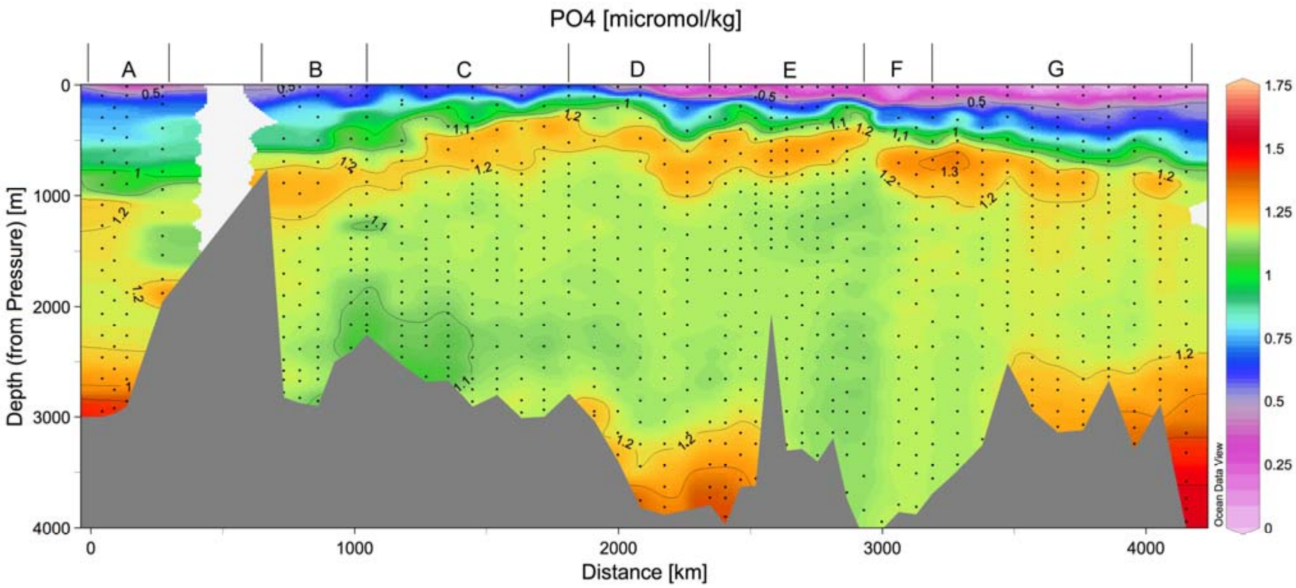

Figure 4.5: *Bottle-derived phosphate (PO_4). Please note that these data have not yet been fully processed.*

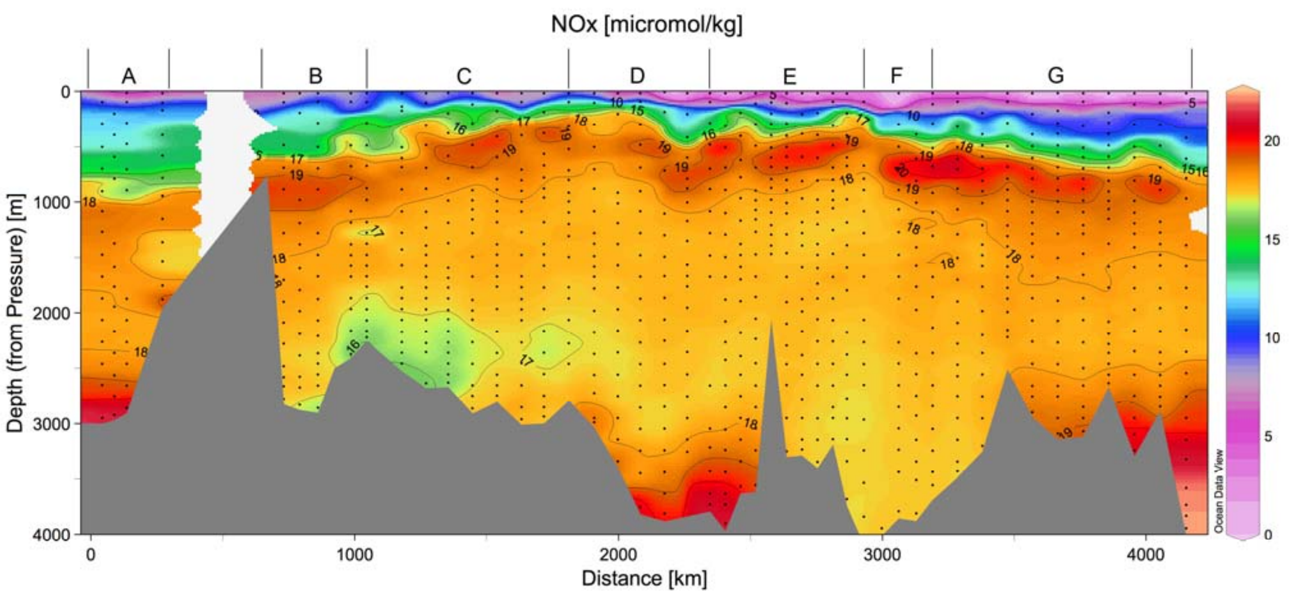

Figure 4.6: *Sketch of preliminary bottle-derived nutrients nitrite+nitrate (NO_x).*

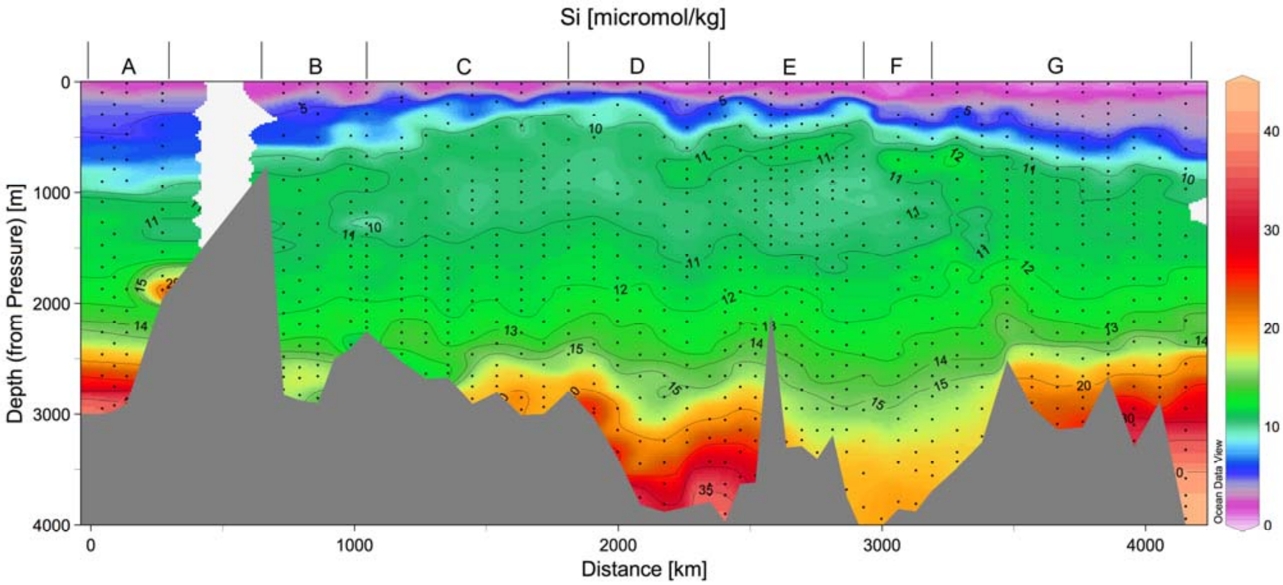

Figure 4.7: *Preliminary bottle-derived silicate (Si).*

5. Acknowledgements

Studies related to physical oceanography conducted during *R/V Pelagia* cruise 64PE278 were carried out in the framework of the German project *Verbundvorhaben Nordatlantik*, Work Package 2.1. Funding by the German Ministery of Science and Education is greatly acknowledged.

The marine chemistry measurements were funded by the Dutch contribution to the European Integrated 'Carboocean', both through the University of Groningen and Royal NIOZ. SvH would very much like to thank the excellent cooperation with and assistance from the technical, administrative, scientific and ship-board personnel at NIOZ.

DK would like to thank Captain John C. Ellen, master of R/V *Pelagia*, as well as the entire crew for "building bridges over troubled waters", being cooperative and open-minded to opinions and discussions. When preparing this cruise, assistance by Marieke Rietveld and Theo Buisman (both NIOZ) was highly appreciated. Bob Koster and Hendrik van Aken (both NIOZ) also provided value help and advice when experiencing problems with the CTD. Therefore, DK would like to thank the NIOZ team for permitting a test station with their CTD/water sample system in use. Further thanks go to Wolfgang Böke, University of Bremen, for remote support and to Evaline van Weerlee, NIOZ, for sharing a good sense of humor, which is definitely necessary when out in the eastern subpolar North Atlantic in early November.

18 November 2007

Dagmar Kieke
chief scientist

6. Appendix

6.1 Station List

Pelagia 64PE278			CTD Stations									Page 1
Prof.	Sta.	Date	Time	Latitude	Longitude	Water Depth	Prof. Depth	Measurements CFCs	CO_2	Nuts	LADCP	Comment
0	0	2007/10/27	08:16	53° 54.57' N	12° 28.92' W	414	372				x	test station
1	1	2007/10/27	09:22	53° 54.50' N	12° 28.79' W	418	406	x	x	x	x	
2	2	2007/10/27	13:31	54° 17.65' N	12° 42.98' W	2960	2954	x	x	x	x	
3	3	2007/10/27	18:41	54° 40.95' N	12° 57.42' W	2930	2929	x	x	x	x	
4	4	2007/10/28	00:35	55° 4.05' N	13° 11.49' W	2872	2866	x	x	x	x	
5	5	2007/10/28	06:00	55° 27.28' N	13° 25.97' W	2780	2585				x	no upcast data
7	7	2007/10/28	14:35	56° 13.60' N	13° 54.54' W	1957	1883	x	x	x	x	
8	8	2007/10/30	01:22	58° 44.26' N	18° 40.21' W	765	768	x	x	x	x	
9	9	2007/10/30	07:08	58° 55.20' N	19° 40.88' W	2820	2784	x	x	x	x	bad CTD data
10	10	2007/10/30	13:45	59° 6.11' N	20° 41.52' W	2848	2833	x	x	x	x	bad CTD data
11	11	2007/10/31	18:40	59° 3.54' N	21° 51.01' W	2878	2863	x	x	x	x	
12	12	2007/11/01	01:15	59° 28.04' N	22° 42.51' W	2482	2465	x			x	
13	13	2007/11/01	07:00	59° 39.07' N	23° 43.18' W	2408	2377	x	x	x	x	
14	14	2007/11/01	13:22	59° 49.89' N	24° 43.36' W	2238	2226	x	x	x	x	
15	15	2007/11/02	21:55	58° 54.44' N	25° 54.59' W	2530	2496	x	x	x	x	
16	16	2007/11/03	05:38	58° 11.85' N	26° 37.73' W	2540	2640	x	x	x	x	
17	17	2007/11/03	15:41	57° 29.64' N	27° 20.79' W	2599	2635	x	x	x	x	
18	18	2007/11/04	00:58	56° 46.83' N	28° 4.14' W	2896	2866	x	x	x	x	
19	19	2007/11/04	08:33	56° 4.20' N	28° 47.53' W	2804	2767	x	x	x	x	
20	20	2007/11/04	15:46	55° 21.67' N	29° 30.73' W	2988	2966	x	x	x	x	
21	21	2007/11/04	22:37	54° 39.17' N	30° 14.06' W	3000	2960	x	x	x	x	
22	22	2007/11/05	06:15	53° 56.56' N	30° 57.22' W	2793	2776	x	x	x	x	
23	23	2007/11/05	13:39	53° 25.03' N	29° 59.39' W	3012	2993	x	x	x	x	
24	24	2007/11/05	20:33	52° 53.36' N	29° 1.46' W	3396	3348	x	x	x	x	
25	25	2007/11/06	03:38	52° 21.76' N	28° 3.63' W	3768	3757	x	x	x	x	
26	26	2007/11/06	11:09	51° 50.11' N	27° 5.61' W	3823	3817	x	x	x	x	
27	27	2007/11/06	18:33	51° 18.44' N	26° 7.84' W	3841	3375	x	x	x	x	
28	28	2007/11/07	01:45	50° 46.88' N	25° 9.95' W	3762	3733	x	x	x	x	
29	29	2007/11/07	07:19	50° 34.36' N	25° 54.35' W	2006	3904	x	x	x	x	
30	30	2007/11/07	12:58	50° 25.67' N	26° 41.24' W	3598	3573	x	x	x	x	
31	31	2007/11/07	18:29	50° 16.93' N	27° 28.26' W	3580	3561	x	x	x	x	
32	32	2007/11/08	00:04	50° 8.19' N	28° 15.24' W	2073	1990	x	x	x	x	
33	33	2007/11/08	04:41	49° 59.52' N	29° 2.10' W	3237	3253	x	x	x	x	
34	34	2007/11/08	10:07	49° 50.76' N	29° 49.19' W	3250	3238	x	x	x	x	
35	35	2007/11/08	15:31	49° 42.03' N	30° 36.06' W	3274	3351	x	x	x	x	
36	36	2007/11/08	21:04	49° 33.36' N	31° 23.10' W	3170	3147	x	x	x	x	

Pelagia 64PE278			**CTD Stations**									**Page 2**
Prof.	Sta.	Date	Time	Latitude	Longitude	Water Depth	Prof. Depth	Measurements CFCs	CO_2	Nuts	LADCP	Comment
37	37	2007/11/09	02:49	49° 24.67' N	32° 10.04' W	3665	3685	x	x	x	x	
38	38	2007/11/09	08:31	49° 15.87' N	32° 57.01' W	4103	3845	x	x	x	x	
39	39	2007/11/09	15:37	48° 46.94' N	32° 25.65' W	3896	3948	x	x	x	x	
40	40	2007/11/09	22:11	48° 17.92' N	31° 54.15' W	3810	3796	x	x	x	x	
41	41	2007/11/10	04:51	47° 48.96' N	31° 22.68' W	3811	3817	x	x	x	x	
42	42	2007/11/10	12:00	47° 19.99' N	30° 51.21' W	3689	3607	x	x	x	x	
43	43	2007/11/10	20:44	46° 55.40' N	29° 46.64' W	3432	3433	x	x	x	x	
44	44	2007/11/11	04:58	46° 30.84' N	28° 42.09' W	3200	3204	x	x	x	x	
45	45	2007/11/11	12:50	46° 6.26' N	27° 37.53' W	2518	2228	x	x	x	x	
46	46	2007/11/11	20:15	45° 41.72' N	26° 32.93' W	2896	2903	x	x	x	x	
47	47	2007/11/12	04:00	45° 17.08' N	25° 28.41' W	3098	3093	x	x	x	x	
48	48	2007/11/12	13:43	44° 52.53' N	24° 23.80' W	3067	3074	x		x	x	
49	49	2007/11/12	22:42	44° 27.96' N	23° 19.27' W	2646	2638	x	x	x	x	
50	50	2007/11/13	07:13	44° 3.41' N	22° 14.68' W	3280	3247	x	x	x	x	
51	51	2007/11/13	17:18	43° 38.86' N	21° 10.13' W	2793	2849	x	x	x	x	
52	52	2007/11/14	03:59	43° 14.29' N	20° 5.56' W	3939	3949	x	x	x	x	
53	53	2007/11/15	08:31	39° 25.92' N	18° 45.97' W	4926	1979					test station