SHORT CRUISE REPORT

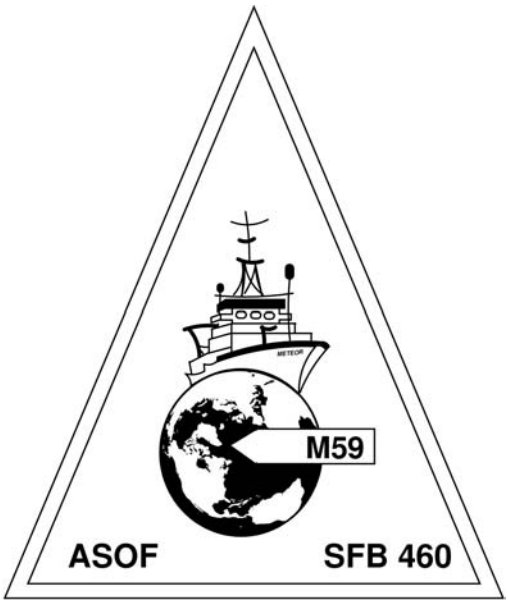
RV METEOR: cruise M-59/2

by : Prof. Dr. Monika Rhein, chief scientist

Institut für Umweltphysik
Abt. Ozeanographie, Universität Bremen

from Reykjavik, Iceland to St. John's, Canada

July 23 to August 29, 2003



With contributions from K.Friis, D.Kieke, C.Mertens, R.Steinfeldt, M.Walter

Prof. Dr. Monika Rhein
Institut für Umweltphysik, Abt. Ozeanographie
Universität Bremen
28334 Bremen, Germany
Phon: ++49 421 218 2408
Fax : ++49 421 218 7018
Email : mrhein@physik.uni-bremen.de

Cruise report of RV Meteor cruise M59/2

Introduction

The deep water masses which are formed and/or modified in the subpolar North Atlantic, are an important part of the climate relevant thermohaline oceanic circulation (THC). Our own measurements made since 1996 in the framework of the national program 'Dynamics of the Thermhaline Circulation Variability' as well as data from other groups have shown, that the hydrographic and tracer characteristic of the deep water masses are subject to significant annual changes. The pursuit of these changes led to the discovery of the main spreading paths and the time scales of spreading along the paths. The quasi synoptic data set of the whole subpolar North Atlantic made it possible to calculate regional and total CFC inventories. From these inventories, the mean formation rate of Labrador Sea Water was estimated to about 5 Sv with interannual changes between 2 and 11 Sv. The M59/2 measurements are a continuation of that effort.
The North Atlantic Ocean stores a disproportionately large amount of anthropogenic CO_2 (C_{ant}) relative to its surface area. Ocean carbon cycle models suggest that most of the associated uptake from the atmosphere occurs in the subpolar gyre. Both models and observations show that C_{ant} is exported from the subpolar gyre (through contact with the atmosphere) into deeper layers of the sub tropical gyre via the the THC. There is, however, considerable disagreement between different models and between models and observations as to the amount of C_{ant} stored within the northern North Atlantic. The overall goal is to quantify the concentration distribution of C_{ant} that is stored as a result of the North Atlantic's thermohaline circulation.

The goals during M59/2 are

- to compare the large scale distribution of the deep water masses with the observations in the time period 1996 – 2001

- to study the export pathways of deep water into the subtropical Atlantic

- to calculate the regional CFC inventories and compare them with the data from 1997 – 2001 and infer the formation rates of the deep water masses

- to calculate the anthropogenic CO_2 inventory in the subpolar North Atlantic compared to the year of the TTO measurements in the early 1980s

Cruise Narrative

The RV METEOR left Reykjavik on July, 23, 19 UTC on favorable weather conditions and headed to the southwest. Outside the 3nm zone, the two vessel mounted ADCPs (75kHz and 38.5kHz) from RD Instruments started to measure continually the velocity distribution in the upper 1200m of the water column. The 75kHz is permanently installed in the foreship, the 38.5kHz is placed in the midship well. Surface salinity and temperature are also recorded, and pCO_2 in the surface water and air as well as TCO_2 are analysed several times per hour.

A CTD test station was successfully carried out at July 24, 15 UTC. A Seabird SBE 9 CTDO system is attached to a 24 x 10L rosette. The CTDO probes measure the vertical profile of temperature, oxygen and conductivity. The conductivity and the oxygen sensors were

calibrated by analysing water samples. Two 300kHz ADCP workhorses from RD Instruments are also attached to the CTD/rosette system to measure the velocity profile from top to bottom, replacing two of the 10L bottles. CFC samples are taken from the 10L water bottles as well as oxygen, nutrients, DIC and C-13.

The station spacing in the Irminger Sea is quite coarse (70 to 100 nm) due to the extensive survey already carried out in the Irmingersea during M59-1. After Station CTD 4, several 10L bottles, which did not function properly were exchanged.

At the southern tip of Greenland (CTD 6), the electrical connection between CTD and wire broke down when the CTD was in 150m depth. The station was abandoned, and the ship headed to CTD7. On the way, the connection and the broken fuse in the assembly board were repaired, and CTD 7 was carried out without any incident. Here, the system was lowered with 0.5m/s instead the usual 1m/s, to obtain enough good data from the 300kHz LADCPs to measure the velocity shear well and thus obtain an estimate for the vertical diffusivity. When leaving the Irmingersea, the station spacing was reduced to about 30 nm. The ship's course was outside the zone where icebergs could be expected. The weather conditions remained favorable, although the wind increased slightly. On July,28 we reached the northernmost station in the Labrador Sea (59°N, CTD 19) , and afterwards the METEOR headed to the southwest along the center of the Labrador Sea. All systems on board are functioning well.

The vm-ADCPs show moderate velocities, like expected in the central Labrador basin with occasionally higher velocities indicating an eddy. Although the wind increased as well as wave height, the weather stayed moderate enough to continue the work without any loss in time. The southernmost station on this section (CTD 30) was reached on early July, 31. The sections usually end at locations which will be the offshore end of the boundary sections to be carried out during M59/3 (chief scientist: Dr. J. Fischer, IFM Kiel, Germany).

On July 31, the METEOR headed to the northeast into the southern Irmingersea. The weather stayed relatively calm, but became cloudier and foggy. The station spacing along this section was enlarged to 37nm, compared to the roughly 30 miles in the central Labradorsea. The northernmost CTD station (CTD 37) was finished on August,1, at about 23 UTC. On the following southward section, the station spacing was 44nm. All systems worked well. The southward section ended with CTD 47 at 49°50‘N early on August, 4 and the METEOR headed towards the east. The Midatlantic Ridge was reached in August, 6, 12 UTC (CTD 55). There the station spacing decreased from 49nm to 36nm.

The METEOR crossed the MidAtlantic Ridge following roughly the Faraday fracture zone. The location at 49°18‘N, 27°52‘W was chosen to study vertical mixing above rough topography by lowering the CTD/LADCP system 5 times (CTD 58-62). Water bottles were closed only at CTD 62. The experiment started on August, 6, 3 UTC and was finished on August, 7, 14 UTC. On the following station (CTD 63) data acquisition was interrupted at several depths while lowering the rosette. The measurements on this station were therefore stopped at 1600m depth and the CTD/rosette was hauled back on board. After repair of the electronic connection between the CTD and the wire, the system worked without failure at the following stations. The easternmost station on the 50°N section was at 26°04‘W (CTD 64).

Afterwards, METEOR set course to the mooring position IM3 at 53°14N, 30°16‘W, and CTD stations were carried out every 40 miles. On August, 9 the chemical pump in the ship's well failed and was replaced while carrying out CTD 70. Since the pump is co-located with the 38.5kHz ADCP, the ADCP direction relative to the ship had to be recalibrated.

The mooring IM3 contains a RAFOS soundsource and releasers. IM3 was reached at August, 9, 13 UTC. Although it was deployed 5 years ago, the releaser responded

immediately and the top elements surfaced about 15 minutes later. The mooring was on board at 15 UTC and the METEOR continued the CTD casts with CTD 71 at 53°07‘N, 30°18‘W. Due to several problems, no LADCP profiles were obtained on CTD 69-71, the entrance of the Gibbs Fracture Zone. On CTD 71, the clock in one of LADCPs experienced a sudden offset of 15 minutes while near the bottom, probably caused by the switch on of the Parasound system.

The mooring IM2 at 56°49‘N, 22°08‘W was reached on August, 12, 6 UTC. Here no releasers were deployed and the mooring had to be dredged. The effort was successfull. At 13 UTC the top buoy surfaced and at 16:15 UTC, the complete mooring was on board.

The METEOR headed to the location of CTD 82 at 54°49‘N, 26°18‘W, and arrived there at August 13, 7:30. The station spacing remained at 45nm. On both deep (about 4700m depth) stations ,CTD 90 and 91, winch problems occurred, which delayed the stations, but did not affect the data sampling. The section from the Rockall Plateau to the eastern end of the WOCE A2 section at 48°N was finished at August, 16, with CTD 95. After finishing CTD 97 (4800m depth), the CTD/rosette system was switched to another winch, which – after some adjustments while carrying out CTD 98 (4600m depth) – worked well. On August 17, CTD 98 at 48°26‘N, 16°40‘W was finished at 22:30 UTC. The following stations towards the MidAtlantic Ridge (MAR) were shallower (<4300m). Beginning at CTD 102, the station spacing was reduced from 45nm to 34nm in order to detect a possible deep flow at the eastern flank of the MAR.

On August, 20 the crest of the Midatlantic Ridge was reached at 14 UTC and CTD 109 was carried out there at 46°50‘N, 27°38‘W. The METEOR crossed to the western Atlantic, and the station spacing remained roughly at 32nm to survey the water masses on the western flank of the ridge. Starting with CTD 116 (46°30‘N, 33°W), August, 22, the distance between the CTD casts increased to 40nm. At 35°W, the velocities at the surface began to increase to more than 1.20 m/s. The increase reached deep into the water column, and about 30-35cm/s were found around 3500m. The velocity of the whole water column was directed to the east, and the METEOR slowed to 9kn while steaming west.

In postprocessing the 38.5kHz and the 75kHz ADCP (permanently installed in METEOR’s foreship) data, a depth dependent bias between the two data sets were discovered, depending also on the heading of the ship. In order to solve the problem, several tests were carried out, and some of these tests required that the METEOR first steamed westward and then back east. Therefore CTD 126 was located further west than CTD 127, although the general steaming direction was to the east.

West of 40°W, the distance between the CTD casts was reduced to 20 miles and at the steep continental slope to 4-8nm in order to resolve the velocity field with the LADCP. At CTD 127, the CTD profile was lost below 1200m depth. In postprocessing the data, the conductivity and oxgen sensors showed substantial noise. This was presumably caused through malfunctioning of the water pumping system due to some object disturbing the flow. On CTD 128 and the following stations all sensors worked properly. The last CTD station (CTD 144, water depth 500m) was finished at August, 27, 1 UTC. Afterwards, the METEOR headed to St. John’s and arrived there at August 28 at 9 UTC.

We thank captain and crew for their cooperation and their excellent work during cruise M59/2.

Technical Aspects

CTDO measurements (Reiner Steinfeldt)

The CTD system used during cruise M 59/2 was a Sea-Bird 911 plus in conjunction with a Sea-Bird release unit with 22 Niskin bottles. Some of the bottles had to be exchanged due to leakage or delayed closing after firing. The CTD system worked properly, except for 2 profiles. One time the communication with the deck unit was disturbed (CTD 63) and the other time (CTD 127) the conductivity and oxygen sensors showed unrealistic values probably due to a particle entering the sensors.

Oxygen samples were taken from all bottles together with nutrients and CO_2 at about every second station, and from 5 bottles at the other stations for calibration purpose. Altogether, 2500 oxygen samples including 350 double samples were analysed by the Winkler titration method. The rms was smaller than +- 0.01 ml/l. On this cruise the new SBE43 dissolved oxygen sensor was brought into operation. At the beginning and after longer cruise tracks without measurements the sensor showed a marked temporal drift, so sets of profiles were calibrated separately. After correction with respect to time, pressure, temperature, the rms difference ranged from 0.03 to 0.06 ml/l for all samples below 1000m depth

Bottle salinities (about 4 each station) were determined using a Guildline Autosal 8400A. The salinometer worked properly without temporal drift during an individual measurement session, the standard deviation of substandards was less than 0.001. The resulting correction for the conductivity cell comprised an offset as well as a linear pressure term. The rms difference between bottle and CTD salinity was 0.003 for all samples below 1000m depth.

After one third of the cruise the batch of standard seawater (Ocean Scientific International IAPSO Standard Seawater) for the standardization of the salinometer was changed from P139 to P141 (K15 = 0.99993, S = 34.997 for both batches). The difference between CTD and bottle salinity, however, changed abruptly by 0.003, in the direction that either the bottle salinities increased by 0.003 or the CTD values decreased by the same amount.
As the conductivity cell showed no temporal drift before and after that event and the autosal had to be recalibratedafter using the new batch (the old autosal standardization resulted in too low salinities for the new batch) it seems that the salinity of batch 139 exceeds that of batch 141 by 0.003. For the CTD salinities the effect is in the opposite direction, with lower salinities if the autosal is standardized with batch 139. Comparing the T/S relationship in the North East Atlantic Deep Water (which is supposed to be almost constant) from this cruise with earlier results shows that the values based on batch 139 are on the lower end and on batch 141 on the upper end of the range with respect to salinity. So it is not clear at the moment, which of the two batches is the more correct one. The preliminary CTD calibration is based on batch 139.

The pressure sensor was calibrated using the mean values from the beginning and end of each profile when the CTD was on deck. The pressure offset was 0.93 (0.83) +- 0.16 (0.18) dbar before (after) the casts. Towards the end of the cruise the pressure offset showed a temporal drift with increasing values before and decreasing values after the cast.

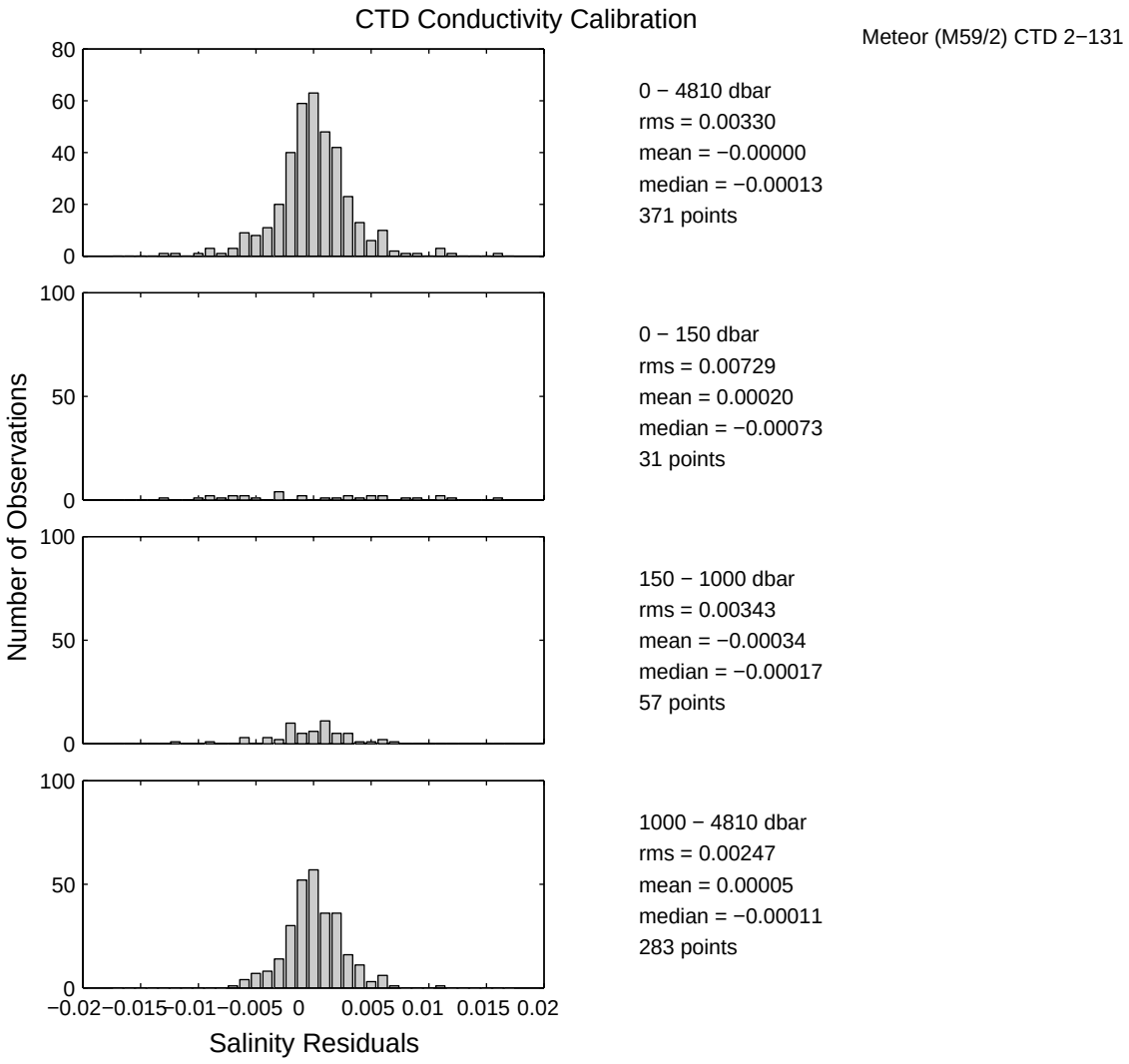


Figure 1 Calibration of the conductivity sensor, cruise M59/2

Lowered ADCP Profiles (Maren Walter)

Two RDI 300kHz workhorse ADCPs were attached to the CTD/water carousel system replacing 2 of the 24 10L Niskin bottles. On 137 CTD stations out of 144, a velocity profile from top to bottom was obtained. The 2 RDI 300 kHz instruments were used in in a synchronized Master-and-Slave mode, with the upward looking (SN 2161) as Slave and the downward looking (SN 1973) as Master. The instruments were powered by an external battery supply, consisting of 35 commercial quality 1.5V batteries assembled in a pressure resistant Aanderaa current meter housing. The system was set to a ping rate of 1 ping/s and a bin length (= vertical resolution) of 10 m.

On CTD 71, when the instrument package was approaching the sea floor, there was a sudden disturbance in the data of the downward looking Master, accompanied by a

leap of the internal clock of the instrument (~15min). This happened before the bottom was in range, and the instrument package was never closer to the sea bed than 10m. The only unusual event during the time of the station was the switching on of the ships' sediment echo sounder (Parasound) when the instrument package was at depth. Since this incident, the SN1973 was unable to detect the distance to the bottom, although the corresponding bottom track velocities are ok and the bottom is clearly visible in the echo amplitude. An inquiry to the manufactorer RDI led to the information that it is a minor problem, and possibly a failure of the instruments firmware. A reinstallation of the firmware did not solve the problem, but since the failure does not affect the quality of the postprocessed data, no further action was taken.

An inverse solution which incorporates the bottom track velocities was used for the postprocessing of the raw data. This resulted in high quality velocity profiles, even for profiles with very weak current velocities and zero mean. The overall performance of the two instruments was excellent. The range of each instrument was typically 150 m in the upper parts of the water column and 60 to 70 m at depth larger than 2500 m, with occasional drops to 50 m where the water was particularly lacking in backscatterers, at depths larger than 4000 m. Thus, the total range of the package reached from100 to 300 m. With typical lowering (1 m/s) and heaving (1.2 m/s) velocities of the instrument package, this range allowed 100 to more than 200 shear estimates per depth bin in the deep water, and more in the shallow layers, depending on the abundancy of backscatterers.

Additional to the standard procedure for full depth velocity estimates, four casts were made with a reduced lowering velocity of 0.5 m/s to study the variability of finescale shear. The reduced lowering enhanced the number of shear estimates per depth bin significantly.

Vessel mounted Acoustic Doppler Current Profiler ADCP (Christian Mertens)

Simultaneous single-ping data were recorded from two RD Instruments Acoustic Doppler Current Profilers: A 75 kHz and a 38 kHz Ocean Surveyor (OS) model with flat phased-array transducers. The 75 kHz OS was mounted into the hull of the ship, and the 38 kHz instrument was located in the ship's well. Both instruments were configured to collect narrow bandwidth water-profile data throughout the cruise. The data from the 75 kHz OS were recorded in 8 m bins to get high vertical resolution data in the upper water column. To achieve maximum range the 38 kHz OS data were collected in 32 m bins. Both systems operated nearly flawless throughout the cruise, except for a crash of the 38 kHz OS data aquisition computer's hard drive on August 27. At that time the ship was already in waters shallower than 600 m except near Flemish Pass, where no 38 kHz OS data were recorded.

Navigation and heading (GPS, Ashtech) information were recorded together with the velocities through two serial interfaces of the data acquisition computer. Both ADCPs used the syncro version of the Fiber Optic Compass (FOG) heading connected directly to the chassis of the ADCP to transform the measured velocities into earth coordinates although it has been found on an earlier cruise (M47/1) that the FOG has a heading dependent error. Because of this error the data were corrected by substituting the syncro-FOG heading values of each single ping with heading values from the Ashtech system. During the first two days the Ashtech receiver had to be restarted several times, but worked well for the rest of the cruise with a coverage of more than 99%. For the short periods of occasional dropouts calibrated digital FOG heading data were used for the heading correction.

The ship's 78 kHz Doppler log is known to cause a considerable reduction in range and data quality of the 75 kHz Ocean Surveyor. Therefore the on station 75 kHz OS data are of reduced quality, as the Doppler log is necessary for navigational purposes during station work. While underway the Doppler log was switched off. Because of the broken temperature

sensor of the 75 kHz OS, a fixed speed of sound was used in the data aquisition to calculate the depth distribution of bins.

A water-track calibration of the angle between the transducers and the Ashtech antenna system has been carried out for both instruments. For the 75 kHz OS the calibration resulted in a misalignment angle of -0.75°. For the 38 kHz OS a misalignment angle of -0.62° and an amplitude factor of 1.006 were determined for the first part of the cruise. On August 9 the transducer had to be raised out of the ship's well to replace a broken pump necessary for the pCO2 measurements. Therefore a recalibration was necessary, that resulted in a misalignment angle of -1.33° and an amplitude factor of 1.002. For the 75 kHz OS no significant amplitude factor was found.

The range of the 75 kHz OS ranged between 600 m and 750 m with lower ranges during periods of rougher sea and station work (due to the running Doppler log). The 38 kHz OS achieved ranges of up to 1300 m, but was much more sensitive to ship motion in rougher sea than the 75 kHz OS where the range decreased to as low as 500 m. Although the wind speed did, in general, not exceed 15 m/s, even total losses of reliable data occured occasionally.

On August 19, spurious echos were incidentally found in the beam 1 echo amplitude of the 75 kHz Ocean Surveyor. The echos showed a regular patter occuring about every half an hour for 10 minutes. These echos were much weaker or absent in the other beams. After testing the ship's echo sounders, Parasound and Hydrosweep, it was found that the interferences were caused by the 38 kHz Ocean Surveyor. The echos disappeared when the 38 kHz OS was switched off on August 20 for a few minutes (Fig.2). Such interference with the 38 kHz OS was not reported on previous cruises for probably two reasons: First it's most striking in beam 1 that is not as routinely checked as the average echo amplitude of all four beams, and second the time between pings of the 75 kHz OS was 2.8 seconds until August 20, instead of 2.4 seconds which is the fastest ping rate of the 75 kHz OS with the choosen configuration. The lower ping interval resulted in a regular pattern of the 38 kHz OS echos compared to the speckled pattern with a 2.4 seconds interval. The time of 2.8 seconds between pings resulted from a failure of the data aquisition program (VmDas) to set the 75 kHz OS to it's highest baud rate of 115200 for transmitting the data from the transducer to the aquisition computer. Instead a lower baud rate was used resulting in a longer time necessary for the data transmission. This has been changed on August 20, and from then on the 75 kHz OS was pinging every 2.4 seconds (the 38 kHz OS had a time between pings of 2.8 seconds throughout the cruise).

With the time between pings of 2.8 seconds and the regular interference pattern a certain amount of data were already considered bad by the transducer firmware, resulting in a reduction of good data below 250 m (Fig.2). Nevertheless, the increased variance of the velocity data indicates that not all measurements were flagged as bad. After the time between pings was changed to 2.4 seconds only few bad data were found below 700 m, but the variance of the velocity data was still higher (especially between 500 m and 700 m) compared to an undisturbed period.

The short station spacing of about 3 nm on the section east of Flemish Cap made it impossible to collect all water samples during the transit time. This allowed to spend some time for two tests where the ship was navigating in oposite directions along the same track, instead of waiting on position. Each test had two legs with one where both ADCPs pinged and the other leg with the 38 kHz OS switched off. Fig. 3 shows the average vertical profiles of 75 kHz OS east and north velocity from both legs respectively and the corresponding 38 kHz velocities together with the rms-difference between both instruments. Overall it appears that the interferences with the 38 kHz OS do not significantly disturb the 75 kHz OS data as no elevated rms-difference was found with the 38 kHz OS running. Instead the rms-

difference is slightly larger on the legs with the 38 kHz OS switched off attributable to ocean variability.

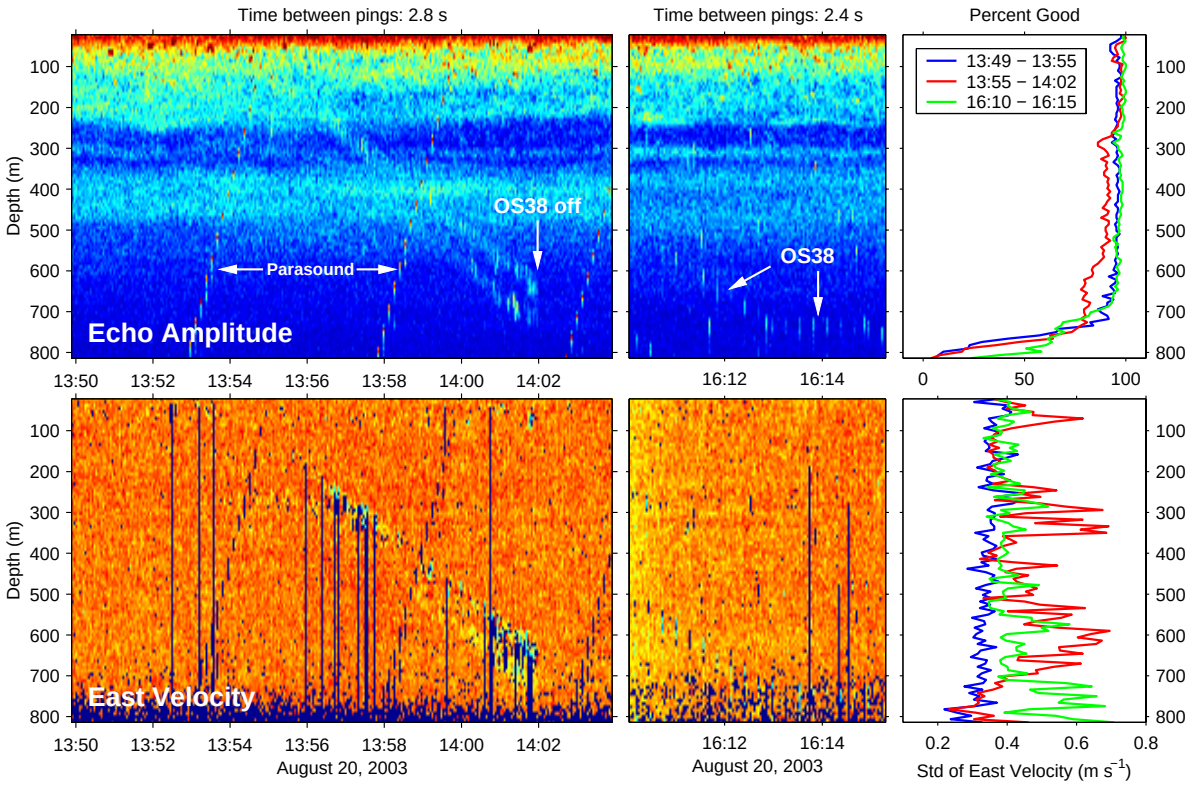


Fig. 2 Single ping beam 1 echo amplitude and east velocity of the 75 kHz Ocean Surveyor (left and middle panel) and vertical profiles of the standard deviation of east velocity and percent good during three time intervals (left panel). The first interval (13:49 - 13:55) shows only echos of the Parasound echo sounder. During the second interval (13:55 - 14:02) interference with the 38 kHz Ocean Surveyor occured. The third interval (16:10 - 16:15) was recorded after the time between pings of the 75 kHz Ocean Surveyor had been changed from 2.8 to 2.4 seconds, showing now scattered echos of the 38 kHz OS.

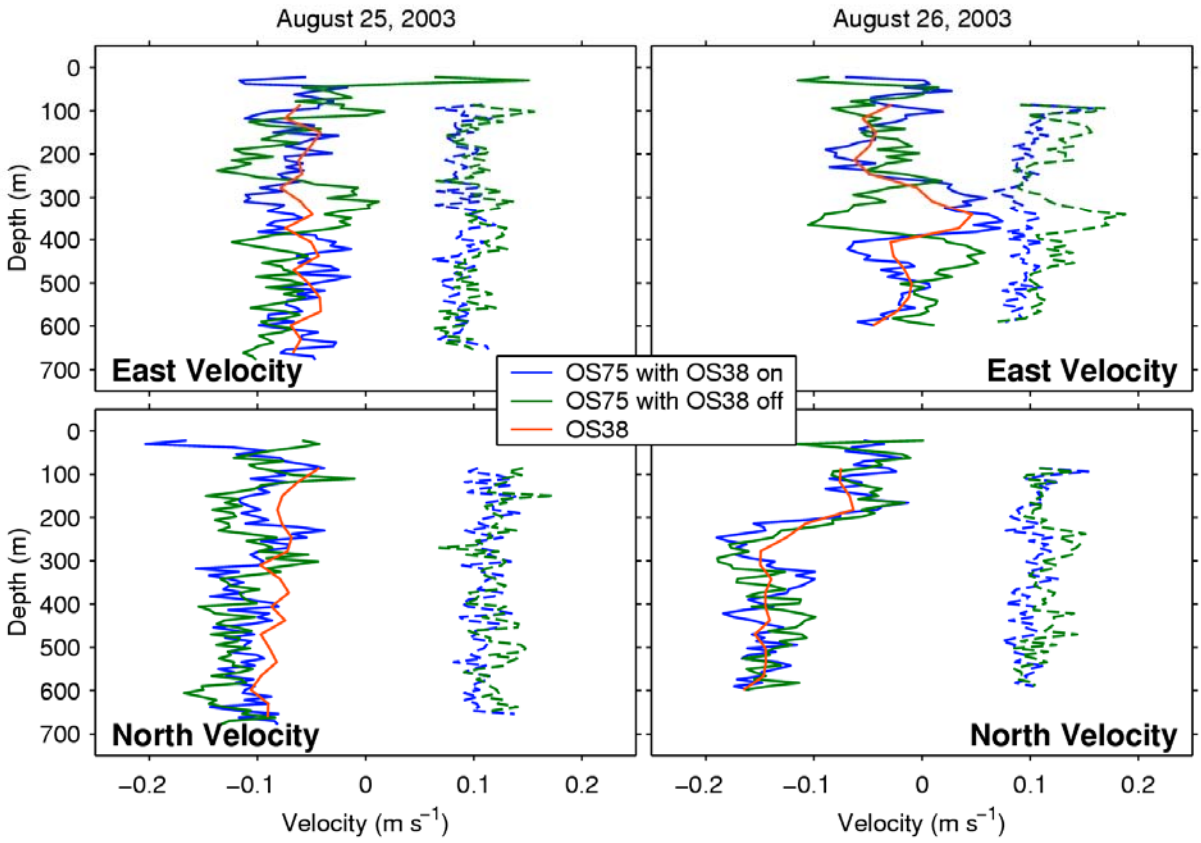


Fig. 3: Vertical profiles of velocity obtained during two tests where the ship was navigating in oposite directions along the same track. On one the these legs both ADCPs were pinging (blue line), while on the way back the 38 kHz OS has been switched off (green line). The corresponding 38 kHz OS profile is shown as red line. The dashed lines show the respective rms-differences between the 38 kHz OS and the 75 kHz OS.

CFC and CCl_4 Analysis (Dagmar Kieke)

During cruise M59/2, the two chlorofluorocarbon components CFC-11 and CFC-12 as well as carbontetrachloride (CCl4) have been measured using gas-chromatographic analysis Altogether, about 2400 CFC samples and 1000 CCl4 samples have been analysed. The scientific focus was on covering all water masses from top to bottom and to observe changes in the tracer concentrations in comparison to previous cruises in these regions. In contrast to the other sections occupied during cruise M59/2, sampling along the Labrador Sea axis section (profiles 19-30) concentrated on the upper 2000m, since here the newly formed Upper Labrador Sea Water (ULSW) and the underlying Labrador Sea Water (LSW) were present as two thick CFC-rich layers which were to be well resolved. Due to the narrow station spacing at the western end of the 47°N section, profiles 130, 132, 134, 136-137, and 139 have been carried out without closing bottles, and thus, no tracer samples are available.

The analysis for both CFC and CCl_4 follows the procedure decribed by Bullister and Weiss (1988). About 100ml of water have been taken from the Niskin bottles using gas-tight glass syringes. The Niskin bottles attached to the CTD/rosette system have been cleaned prior the cruise using isopropanol. Valves, tabs and O-rings have also been removed and cleaned. O-rings have additionally been dried in a vacuum oven. The amount of about 20 ml has then been transferred to a purge-and-trap gaschromatographic unit. With nitrogen as a carrier gas, the gaseous components within a water sample are separated using a packed column in case of CFC and a capillary column in case of CCl_4. For signal detection, an electron-capture detector (ECD) is attached. The ECD signals are calibrated and converted into CFC and CCl_4 concentrations by means of a known standard gas (CFCs: S-37 for all profiles; CCl4: S-34 until profile 81 and S-41 for profiles 82-144). Before and after each profile, calibration curves with up to six different volumes have been generated, assuming that the efficiency changes linearly in time between two respective calibration curves. All tracer concentrations are reported in pmol/kg using the SIO-93 scale.
119 CFC-samples have been analysed twice, resulting in a reproducibility of 0.6% for CFC-12 and 0.5% for CFC-11 (Fig.4). To check for system contamination, measurements of the atmospheric CFC concentration have been carried out inside the vessel's laboratory and outside on the main deck showing slightly increased concentrations in comparison to clean air.

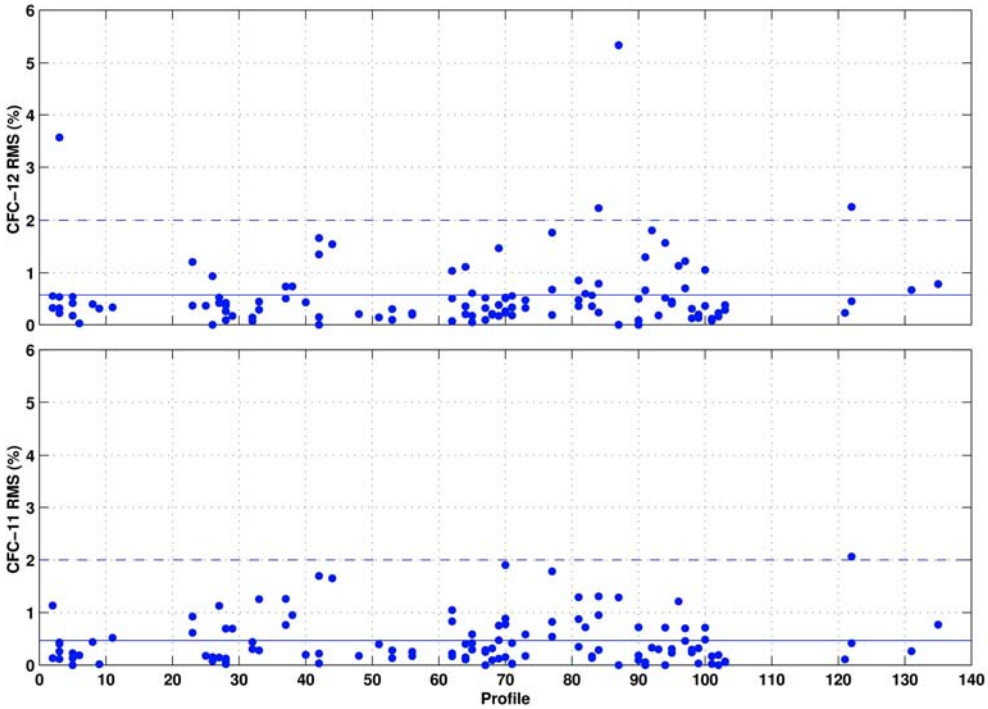
At profiles 27 and 28, six respective CFC-offline samples have been taken using glas ampoules. These have been sealed by transferring nitrogen cleaned by molsieves into the neck of the ampoules and afterwards fusing the upper end of the ampoules. The samples from the ampoules will be analysed after the cruise in the CFC laboratory at the University of Bremen. Though their uncertainty is supposed to be somewhat higher than the direct measurement on board, together with the tracer analyses performed during M59/3 they will allow a direct comparison between the CFC system run by the University of Kiel and the system at the University of Bremen.

In the West European Basin we encountered a thick bottom layer with very low CFC concentrations, indicating a rather old water mass. The two volume loops for the gas standard measurements (nominal 2ml and 5ml) are too large to precisely measure these small concentrations, since their use aims at the determination of CFC concentrations in the surface to deep water masses, which generally carry higher concentrations. The accuracy of this CFC-poor bottom water is about 0.03 pmol/kg. CFC-free water masses are not present in the subpolar North Atlantic.

Unfortunately, malfunction of a valve presumably caused during the transport delayed reliable measurements of CCl_4 till CTD 48. After CTD 63, a purge-gas leakage in the CCL_4 system occured, leading to extreme low concentrations and finally to the breakdown of measurements. The CCl_4 measurements continued after CTD 73. The calibration curves, however, remained instable, complicating the analyses of this tracer. Careful reanalysis will be done at the home laboratory. One Niskin bottle which has been closed near the sea bottom showed a considerable CCl_4 peak over at least six profiles (CTD 85-90). There was, however, no contamination in other parameters like CFCs, analysed from the same bottle.

For the CFCs, it turned out that the calibration of the component CFC-12 is far more stable than the one of CFC-11. Significant blanks or leaks have not been observed during the cruise. Nevertheless, the CFC-11 calibration curves succumbed to larger variability than the ones of CFC-12 . Exchange of the drying agent (magnesiumperchlorate) in the purge-and-trap unit did not bring a significant improvement. The calibration curves after profile 112 have been considerably affected by too small CFC-11 values compared to CFC-12. Since the decrease in concentrations seems only to occur in the gas standard, but not in the water analysis, the CFC-11/CFC-12 ratios in seawater were far too high for the young water masses like recently formed Upper Labrador Sea Water. To correct this effect, the CFC-11 calibration curve after profile 112 is believed to be the last good one. For the following measurements, it was assumed that the efficiency of CFC-12 and CFC-11 varies in parallel. The data set now is self-consistent with the highest CFC-11/CFC-12 ratio appearing in regions, where the oldest water masses are present and vice versa. Nevertheless, the mean sea surface saturations for both components (CFC-12: 105%, CFC-11 108%) are still too high outside regions where mixing of cold and CFC-rich waters with warm and CFC-poor waters could have explained these high values.

Fig. 4 Precision (%) of the CFC-12 and CFC-11 double samples versus profile number.



Marine Chemistry (Karsten Friis)

On the Meteor cruise 59/2 the marine chemistry group investigated on the discrete shipboard analysis of nutrients (phosphate, silicate, nitrate, nitrit), oxygen, and inorganic carbon parameters, i.e. total dissolved inorganic carbon (C_T), total alkalinity (A_T), and pH, from hydrocasts. Samples for the onshore determination of the $^{13}C/^{12}C$-ratio ($d^{13}C$) were stored. From a continuous water supply of the ships moon pool the sea surface partial pressure of CO_2 (pCO_2) and also sea surface C_T were determined.

Sampling procedure of parameters sensitive to gas exchange

Oxygen samples

The oxygen sampling was done in 100 mL NS 29 wide neck bottles with ground glass stoppers. A short drawing tube extending from the Niskin bottle to the bottom of the sample bottle was used to fill sample bottles. When no more bubbles could be observed either in the tubing and the bottle it was overflown at least twice its volume. Then 1 mL $MgCl_2$ and 1 mL KI/KOH solution have been added from two dispensers with small tubes reaching to the bottle bottom. The glass stoppers were used to displace the upper 25 mL water and also to close the bottle. The bottle was shaken carefully for at least one minute.

CO_2 samples

Two samples for each depth were collected in 500 ml glass bottles with ground glass stoppers. The bottle volume enables two analyses to be performed on a single sample (*p*H first followed by A_T). The second bottle was used to measure the C_T. The filling procedure was done with a short drawing tube extending from the Niskin bottle to the bottom of the sample bottle. The bottles were rinsed with about 50 mL of sample, then filled up from the bottom and overflown by at least 250 mL of water. A head space of about 1% was achieved by clamping and removing the tubing. After closing the bottles the stoppers were held down firmly with a rubber band. All samples were analyzed within 24 hours of being collected.

Sampling and storage of $d^{13}C$ samples

780 samples for onshore ^{13}C mass spectrometry were collected. 100 mL samples were taken carefully using a short drawing tube extending from the Niskin bottle to the bottom of the sample bottle. Each bottle was overflown by about twice its volume. A head space of about 1% was achieved by a displacement stopper that was removed after water displacement. Then each sample was immediately poisoned with 100 µL saturated solution of $HgCl_2$ and finally crimp-sealed for storage and analysis onshore.

Total dissolved carbon dioxide analysis (discrete and underway)

The C_T analyses were made by a coulometric titration method using the SOMMA (single operator multi-parameter metabolic analyzer) system (JOHNSON ET AL., 1993). The SOMMA collects and dispenses an accurately known volume of seawater to a stripping chamber, acidifies it, sparges the CO_2 from the solution, dries the gas, and delivers it to a coulometer cell. The coulometer cell is filled with a partially aqueous solution containing monoethanolamine and a colorimetric indicator. A platinum cathode and a silver anode are positioned in the cell and the assembly is positioned between a light source and a photodetector in the coulometer. When the gas stream from the SOMMA stripping chamber passes through the solution, CO_2 is quantitatively absorbed, reacting with the ethanolamine to form a titratable acid. This acid causes the color indicator to fade. When the photodetector measures a color fade, the coulometer activates a titration current to neutralize the acid until the solution reaches its original color. The titration current is integrated over the time of the analysis, which provides a determination of CO_2 in the sample. Each sample is sparged and titrated until the amount of CO_2 coming from the stripping chamber is at blank level for four minutes - this was usually between 10 and 16 minutes per sample. An integral part of the SOMMA is a gas calibration system that is used to calibrate the coulometer, i.e. coulometer/titration cell combination. In the gas calibration procedure, each of two gas

sample loops is filled with pure CO_2 gas, the temperature of the loop and the atmospheric pressure are automatically measured so that the mass of CO_2 in the loop can be calculated. The contents of the loop are then injected into the SOMMA gas stream - following the same path through the stripping chamber and to the coulometer cell that is used by water sample sparge gas. The percent recovery of the CO_2 is calculated (typically for this cruise about 99.95 - 99.98%) and a „calfactor" is entered into the software in order to determine the sample C_T following the equation:

$$C_T = \text{Calfactor} * \mu\text{mol} * (1000 / V_t * \rho)$$

Here, µmol is the result of the sample coulometric titration, V_t the sample volume at the sample temperature and salinity (T = 20°C), and ρ the density of sea water at the sample temperature and salinity. One coulometer cell is capable for the analysis of 32 to 60 individual samples, afterwards the titration cell has to be replaced and the calibration procedure has to be done again.
After the instrument for the discrete hydrocast samples was calibrated, as additional reference, a bottle of certified reference material (CRM) and two duplicate samples per station were analyzed. The CRM bottles were prepared by Dr. Andrew Dickson's laboratory at the Scripps Institution of Oceanography. Normally the CO_2 content measured by the SOMMA should be within two µmoles/kg (about 0.1%) of the certified value.
A second SOMMA was used for sea surface C_T-determination along the wohle cruise track. The underway SOMMA modification is described in detail in JOHNSON ET AL. (1999). It uses a flow-through bottle that was connetcted to the water supply from the ships moon pool. The C_T data were collected parallel to the pCO_2 data (see below). A merge programm will bring the C_T and pCO_2 data in the right order, after the cruise.
When a new coulometer cell has been prepared the underway SOMMA was in an autonomous run mode and feed quasi-continuous from the water supply every 15 to 25 minutes. The latter was depending on the titration duration which was followed by a 5 min delay after each analysis. The standardization and quality control was done by: (I) repeated gas calibrations, (II) repeated C_T surface measurements on hydocast stations, (III) parallel analysis of 58 underway samples on both SOMMA systems, and (IV) a few CRM measurements on the underway system. While the first two controls allow a precision estimate, the contols (III) and (IV) are capable of an accuracy assessment.

Alkalinity determination
Total Alkalinity (A_T) is determined by titration of seawater with a strong acid, following the electric motoric force with a proton sensitive electrode. The titration curve shows two inflection points, characterizing the protonation of carbonate and bicarbonate, respectively. The acid consumption up to the second point is equal to the titration alkalinity.
Alkalinity was determined by a semi-automatic analysator, the VINDTA instrument (Versatile Instrument for the Determination of Titration Alkalinity). It consists of two parts, the titration cell with its manifold for filling, draining and acid delivery and the data acquisition and system control unit (MINTROP ET AL., 2000).
The sea water titration was done in an open cell by twenty eight 150 mL additions of hydrochloric acid (0.1 molar) to 100 mL sample. A stir bar inside the cell mixed acid and sample. The analysis was performed at 25 °C, which was maintained by a water bath. The titration was so potentiometrically followed by a pH-sensitive Orion™ Ross-electrode (model 8101) a Metrohm™ Ag-/AgCl-reference electrode (model 6.0729.100). The difference in *p*H potential was measured by a *p*H-meter which delivered the data to the computer for the recording and calculation of total alkalinity.
The standardization was done the same way as the C_T samples, running a CRM (see above) in the beginning and two duplicats per station and finishing with a CRM. The alkalinity results should be within a range of 2-3 µmoles of the CRM values.

*p*H *determination*

The *p*H was determined by a spectrophotometric method that is based on the absorbance spectrum of a *p*H-indicator dye. All measurements were made with an automated system described in FRIIS (2001), using meta-cresol purple as indicator dye. The indicator was calibrated for *p*H on the total seawater scale (pH_T) by CLAYTON AND BYRNE (1993). For the *p*H calculation procedure we followed the description in DOE (1994).
Six samples could be analyzed per hour, which was one complete hydrocast within 4 hours. The indicator dye was dissolved in seawater and for analysis the mixing ratio (sample:indicator) was about 650:1. The analysis was performed at 21 °C ± 1 °C. During the spectrophotometric detection the exact temperature was measured by a calibrated Platinum resistence thermometer [± 0.05 °C]. Afterwards all *p*H data were fitted to 21 °C. This was done with the computer program ‚CO2SYS' by LEWIS AND WALLACE (1998) using the dissociation constants after Mehrbach et al. (MILLERO AND DICKSON, 1987) constants and the corresponding A_T or C_T value. The standardization was done the same way as the C_T ans A_T samples, running a CRM in the beginning and two duplicats per station and finishing with a CRM. The *p*H results should be within a range of 2-3 µmoles of the CRM values.

CO_2 partial pressure determination
The fourth analytical instument measured the pCO_2 in surface water and in the overlying atmosphere. The used automated underway system with a non-dispersive infrared gas detector for CO_2 was continuously operated along the cruise track. A continous flow of seawater was drawn at 5 m depth from the ship's moon pool which was equipped with a CTD. Every minute a pCO_2 data point together with temperature and salinity from the CTD were logged along with the position data from an independent GPS system. Previous work (KÖRTZINGER ET AL. 1996) has shown that the system is accurate and precise to ± 2 µatm. But in contrast to earlier expeditions we dryed the CO_2 gas before its gas phase concentration determination. The drying was done in three levels: First by a Peltier cooler, second by a Naphion© tubing with an out drying gas counter current, and at last by a $Mg(ClO_4)_2$-water trap directly before the infrared analyzer. The drying implied a small gas flow into the pCO_2 equilibrator line. This gas flow was pre-equilibrated with the systems waste water for minimum CO_2-perturbations from outside. The instrument was calibrated every twelve hours using three different standard gases (250 ppmv, 350 ppmv, 450 ppmv) from the US National Oceanographic and Atmospheric science Administration (Boulder, Colorado) with exactly known CO_2 (± 0.04 ppmv) concentrations. Atmospheric CO_2 samples were taken from an air supply that was fixed on the monkey deck. Due to some instrumentation difficulties we started the latter atmospheric measurements not until the 12th of August.

Nutrients and Oxygen determination

The nutrient analysis (nitrate, nitrite, phosphate, silicate) was made with an autoanalyzing system according to GRASHOFF ET AL. (1999). Oxygen was analyzed according to a standard titration after Winkler (GRASHOFF ET AL., 1999).

The quality control of the discrete CO_2 measurements was performed with the help of certified reference materials (CRM) and analysis of duplicates that were taken approximately every tenth sample. The CRMs were provided by Dr. Andrew Dickson and analyzed by Dr. C. D. Keeling by vacuum extraction with manometric detection at the Scripps Institution of Oceanography in La Jolla, California. The CRMs are certified for C_T and A_T only, but have to have a constant *p*H. These standards are used to determine the accuracy and performance of the systems. The duplicates give an estimate of the precision of the analytical determination. An overview of the quality controls of C_T and A_T is shown in Table 1 and Fig.5. The control samples show a very good agreement with the achievable accuracy and precision estimates according to MILLERO ET AL. (1993), which is still state-of-the-art. Their accuracy estimate is $\pm$ 2 µmol kg^{-1} in C_T and $\pm$ 4 µmol kg^{-1} in A_T with precision estimates of $\pm$ 1 µmol kg^{-1} and $\pm$ 2 µmol kg^{-1}, respectively.

	C_T	**A_T**
1.1.1.1.1.1 CRM: 1.1.1.1.1.1.1 Analyzed bottles	129	116
Batches used	(56, 58, 60)	(56, 58, 60)
Mean deviation from certified CRM value	+ 0.02 µmol/kg	+ 0.02 µmol/kg
(standard deviation)	($\pm$ 1.48 µmol/kg)	($\pm$ 1.93 µmol/kg)
1.1.1.1.1.2 Duplicates: Analyzed pairs	120	119
Mean deviation from duplicate value	1.2 µmol/kg	2.3 µmol/kg
(standard deviation)	($\pm$ 1.4 µmol/kg)	($\pm$ 1.8 µmol/kg)

Tab. 1: Key data of the discrete C_T, and A_T analyses. The CRM measurements give an accuracy estimate, the duplicate measurements a precision estimate.

The *p*H quality control from 62 mesurements of CRM batch 60 showed a significant drift of the spectrophotometric pH measurements of about 0.04 pH units over the whole cruise. The drift was linear with time. Since the spectrophotometric determination itself takes new reference and indicator spectra for each single analysis, a drift can not be explained by the spectrophotometer itself. So the drift cause is probably from a drift of the temperture sensor within the cuvette. But this has to be tested on shore. Due to the drift record of CRM a precise correction of the drift should be possible. The day-to-day precision was better than 0.002 pH units.

For the underway SOMMA system the sea surface C_T measurements on hydrocast locations got a central position for the quality control. One hydrocast took usually between 2 and 3.5 hours and had nearly no sea surface C_T (nor pCO_2) variation. So a precision estimate of 1.04 µmol kg^{-1} could be done from the repeated underway C_T mesurements, which is shown in

Fig. 6 A. A performed cross-check analysis between the well standardized discrete and the underway SOMMA show very good shipboard results from 56 underway samples and two CRM measurements in Fig. 6B.

The underway samples were also taken on the hydrocast locations. But since the underway SOMMA system did not have a salinity cell, it was not capable of immediate density calculations that are needed for the
SOMMA software calculation of C_T in µmol kg^{-1}. That far the software used a default salinity of zero for the underway samples, leading to too approximately 2.7 percent too high C_T values from the underway system. The cross-check results look very promising and will be recalculated after the underway C_T samples are merged with the moon pools CTD values.

Nutrients and oxygen quality control

The accuracy for nutrient analysis was approximately 1 % of the nutrient standards. For precision estimates duplicate samples were taken and analyzed at about every tenth sample. The corresponding accuracy and precision (± standard deviation / in brackets) estimates were 0.205 (± 0.09) µmol/kg for nitrate, 0.005 µmol/kg for nitrit, 0.025 (± 0.013) µmol/kg for phosphate and 0.5 (± 0.06) µmol/kg for silicate. Additionally to our own standard we used nutrient standard solutions from Ocean Scientific International Ltd. (Petersfield, Hants, UK) for comparision. These commercial standards had to be diluted by a factor of 40 (phosphate), 33 (nitrate), 100 (nitrit) and 20 (silicate) to fit our detection range. The measured concentrations of the diluted standards where within the accuracy from dilution and system accuracy. The oxygen measurements were done with a mean precison of ± 0.51 µmol/kg estimated from duplicate analysis of 360 samples.

References

DICKSON, A.G., 1990. The oceanic carbon dioxide system: planing for quality data, JGOFS News, (2): 2.

DOE, 1994. Handbook of methods for the analysis of various parameters of the carbon dioxide system in sea water. ORNL/CDIAC-74, U. S. Dep. of Energy, Oak Ridge Natl. Lab., Oak Ridge, Tenn., USA.

FRIIS, K., 2001. Separation von anthropogenem CO_2 im Nordatlantik – Methodische Entwicklungen und Messungen. Dissertation. Christian-Albrechts-Universität zu Kiel, Kiel, 137 pp.

GRASSHOFF, K., KREMLING, K. AND EHRHARDT, M. (1999): Methods of seawater analysis. 3rd edition, Verlag Chemie, Weinheim.

JOHNSON, K.M., KÖRTZINGER, A., MINTROP, L., DUINKER, J.C., WALLACE, D.W.R., 1999. Coulometric total carbon dioxide analysis for marine studies: measurement and internal consistency of underway TCO2 concentrations. Mar. Chem., 67: 123-144.

JOHNSON, K.M., WILLS, K.D., BUTLER, D.B., JOHNSON, W.K. UND WONG, C.S., 1993. Coulometric total carbon dioxide analysis for marine studies: Maximizing the performance of an automated gas extraction system and coulometric detector. Mar. Chem., 44(2-4): 167-188.

KÖRTZINGER, A., THOMAS, H., SCHNEIDER, B., GRONAU, N., MINTROP, L. UND DUINKER, J.C., 1996. At-sea intercomparison of two newly designed underway pCO2 systems - encouraging results. Mar. Chem., 52(2): 133-145.

LEWIS, E. UND WALLACE, D.W.R., 1998. CO2SYS - Program developed for the CO2 system calculations. Carbon Dioxide Inf. Anal. Center; Report ORNL/CDIAC-105, Oak Ridge, Tenn., U.S.A.

MILLERO, F.J., BYRNE, R.H., WANNINKHOF, R., FEELY, R., CLAYTON, T., MURPHY, P. UND LAMB, M.F., 1993. The internal consistency of CO_2 measurements in the Equatorial Pacific. Mar. Chem., 44(2-4): 269-280.

MINTROP, L., PEREZ, F.F., GONZALEZ-DAVILA, M., SANTANA-CASIANO, J.M. UND KÖRTZINGER, A., 2000. Alkalinity determination by potentiometry: intercalibration using three different methods. Ciencias Marinas, 26(1): 23-37.

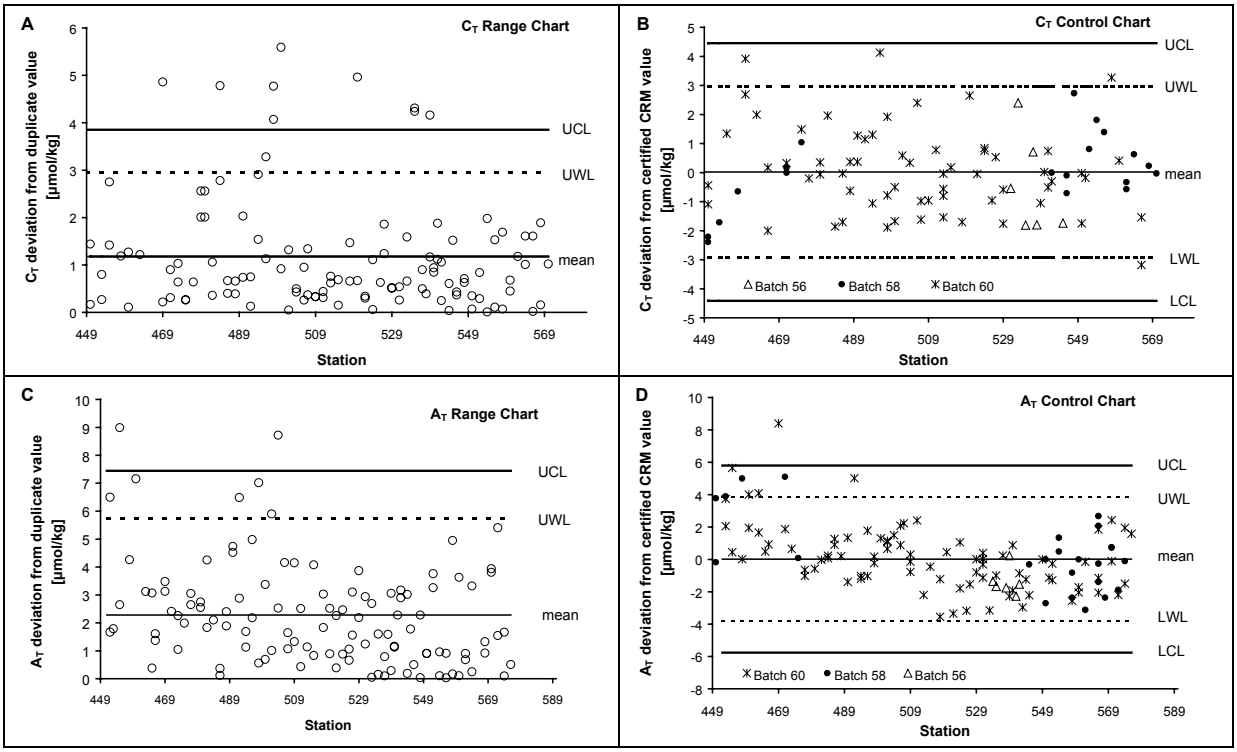


Fig. 5 A-D: Quality charts for total dissolved inorgnaic cabon and total alkalinity. The range charts on the left-hand side are based on duplicate analysis of usually two niskin bottles per hydrocast. The control charts on the right-hand side are based on measurements of certified reference materials (CRM), that was at minimum one control measurement per hydrocast and parameter. Also shown are ‚warning' and ‚control limits' (WL and CL), these are included according to a standard control procedure for marine CO_2 parameter analysis in DOE (1994). The ‚warning limits' result in multiplying the standard deviation by two and the ‚control limits' by three. About 95 % of the plotted points should be within the warning limits.

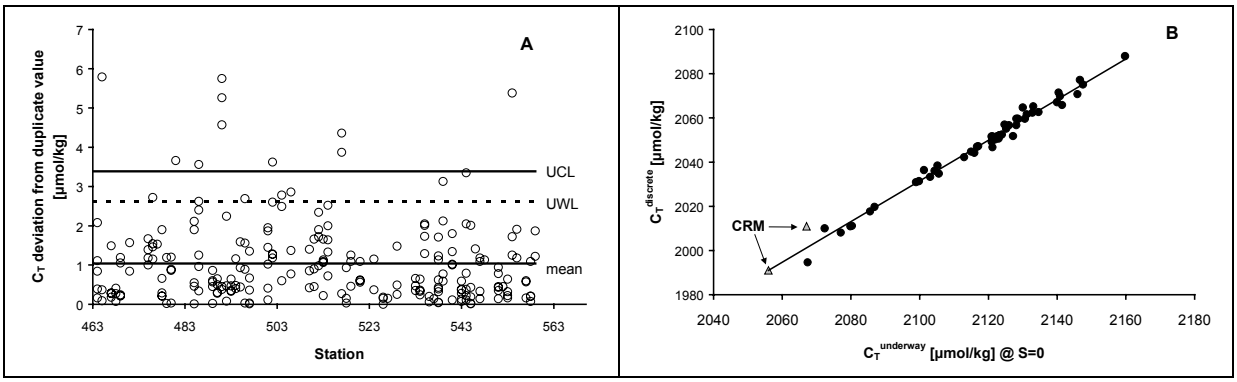
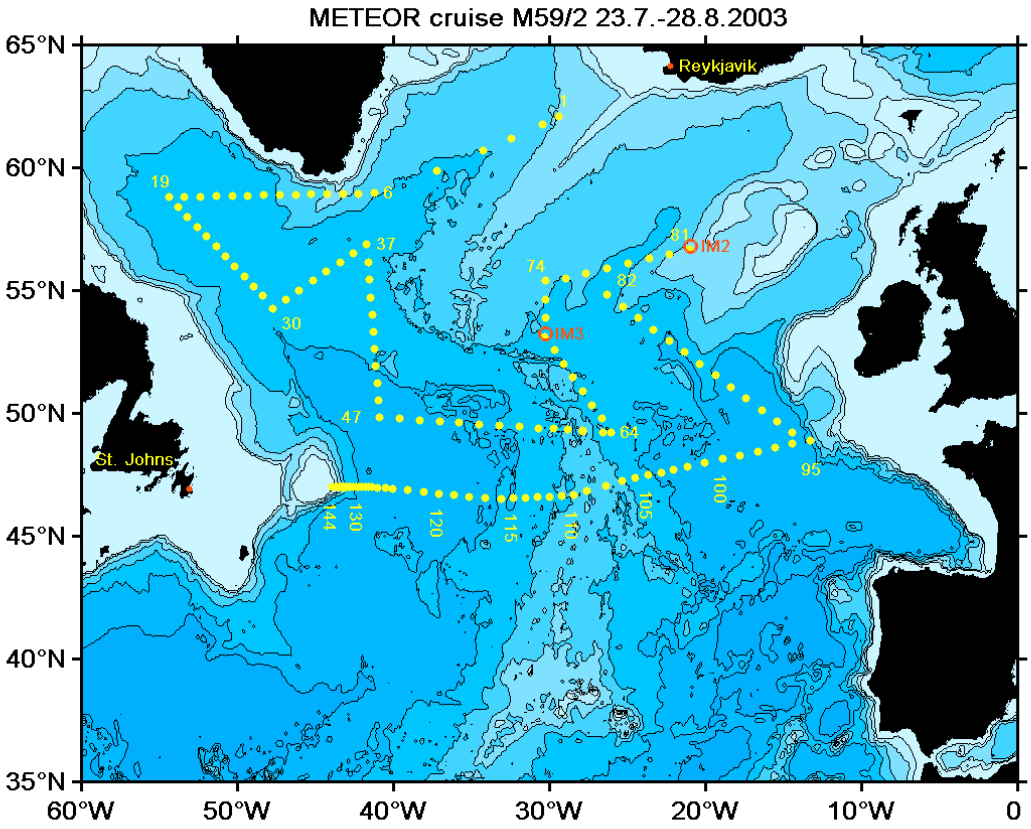


Fig. 6 A/B: Quality charts for the C_T measurements of the underway SOMMA system. Fig. A shows the C_T precision on hydrocast locations of 1.04 µmol/kg. Fig. B shows the cross check between the discrete and the underway SOMMA. The difference between the two systems is due to a wrong reference salinity of zero with the underway system. A correct salinity adjustment of the underway C_T will be done after the cruise.



CRUISETRACK METEOR M59/2

Meteor M59/2		**CTD Stations**					**Page 1**				
Prof.	Sta.	Date	Time	Latitude	Longitude	Water Depth	Prof. Depth	Measurements CFCs	CO_2	LADCP	Comment
1	449	2003/07/24	15:09	62° 5.38' N	29° 25.46' W	1999	1958	x		x	
2	450	2003/07/24	19:41	61° 45.47' N	30° 26.09' W	2106	2053	x	x	x	
3	451	2003/07/25	02:38	61° 10.96' N	32° 28.98' W	2676	2642	x		x	
4	452	2003/07/25	09:20	60° 42.03' N	34° 14.49' W	3035	2999		x	x	
5	453	2003/07/25	19:12	59° 52.45' N	37° 11.72' W	3100	3109	x	x	x	
6	455	2003/07/26	08:39	58° 57.91' N	41° 12.83' W	2878	2824	x	x	x	
7	456	2003/07/26	14:01	58° 56.92' N	42° 13.96' W	2381	2356	x		x	
8	457	2003/07/26	18:10	58° 56.45' N	43° 15.20' W	1742	1698	x		x	
9	458	2003/07/26	22:10	58° 56.20' N	44° 15.26' W	1860	1818	x	x	x	
10	459	2003/07/27	02:02	58° 55.04' N	45° 16.05' W	2482	2434	x		x	
11	460	2003/07/27	06:11	58° 54.51' N	46° 17.07' W	2713	2670	x	x	x	
12	461	2003/07/27	10:30	58° 53.58' N	47° 17.91' W	3024	2966	x			
13	462	2003/07/27	15:07	58° 52.85' N	48° 18.87' W	3380	3331	x		x	
14	463	2003/07/27	20:03	58° 52.06' N	49° 20.23' W	3488	3435	x	x	x	
15	464	2003/07/28	00:45	58° 51.45' N	50° 21.00' W	3452	3488	x		x	
16	465	2003/07/28	05:34	58° 51.02' N	51° 22.06' W	3452	3480	x		x	
17	466	2003/07/28	11:50	58° 49.62' N	52° 23.18' W	3502	3453	x	x	x	
18	467	2003/07/28	17:33	58° 49.53' N	53° 24.09' W	3430	3379	x		x	
19	468	2003/07/28	22:21	58° 48.97' N	54° 24.72' W	3430	3376	x		x	
20	469	2003/07/29	02:53	58° 24.44' N	53° 48.11' W	3460	3408	x	x	x	
21	470	2003/07/29	07:34	58° 0.49' N	53° 11.93' W	3500	3464	x		x	
22	471	2003/07/29	12:33	57° 35.95' N	52° 35.53' W	3542	3485	x	x	x	
23	472	2003/07/29	17:18	57° 11.98' N	51° 59.01' W	3540	3501	x		x	
24	473	2003/07/29	22:11	56° 48.05' N	51° 22.80' W	3614	3553	x		x	
25	474	2003/07/30	03:06	56° 23.48' N	50° 47.01' W	3658	3608	x		x	
26	475	2003/07/30	08:03	55° 59.49' N	50° 10.46' W	3710	3652	x	x	x	
27	476	2003/07/30	12:56	55° 34.96' N	49° 34.54' W	3711	3644	x		x	
28	477	2003/07/30	17:49	55° 10.97' N	48° 57.90' W	3780	3682	x	x	x	
29	478	2003/07/30	23:47	54° 46.87' N	48° 21.50' W	3790	3773	x		x	
30	479	2003/07/31	05:21	54° 16.00' N	47° 45.44' W	3800	3792	x		x	
31	480	2003/07/31	11:03	54° 38.47' N	46° 53.55' W	3400	3439	x	x	x	
32	481	2003/07/31	16:29	55° 0.99' N	46° 1.97' W	3466	3396	x		x	
33	482	2003/07/31	21:47	55° 24.05' N	45° 10.39' W	3456	3387	x	x	x	
34	483	2003/08/01	03:28	55° 46.49' N	44° 17.91' W	3243	3200	x		x	
35	484	2003/08/01	08:56	56° 8.90' N	43° 26.70' W	3415	3384	x	x		
36	485	2003/08/01	14:26	56° 31.48' N	42° 34.49' W	3247	3168	x		x	

Meteor M59/2		**CTD Stations**					**Page 2**				
Prof.	Sta.	Date	Time	Latitude	Longitude	Water Depth	Prof. Depth	Measurements CFCs	CO_2	LADCP	Comment
37	486	2003/08/01	19:42	56° 53.97' N	41° 42.97' W	3370	3347	x	x	x	
38	487	2003/08/02	01:36	56° 9.94' N	41° 38.49' W	3237	3209	x		x	
39	488	2003/08/02	07:20	55° 26.00' N	41° 32.96' W	3100	3060	x	x	x	
40	489	2003/08/02	12:52	54° 41.97' N	41° 27.90' W	3249	3219	x		x	
41	490	2003/08/02	18:26	54° 0.48' N	41° 23.08' W	3250	3626	x	x	x	
42	491	2003/08/03	00:29	53° 18.57' N	41° 17.93' W	3441	3414	x		x	
43	492	2003/08/03	06:20	52° 37.02' N	41° 12.85' W	3900	3905	x	x	x	
44	493	2003/08/03	12:35	51° 55.51' N	41° 7.93' W	3480	3453	x		x	
45	494	2003/08/03	18:14	51° 13.51' N	41° 3.01' W	4150	4136	x	x	x	
46	495	2003/08/04	00:23	50° 32.00' N	40° 57.92' W	4378	4381	x		x	
47	496	2003/08/04	06:30	49° 49.85' N	40° 52.86' W	4420	4392	x	x	x	
48	497	2003/08/04	13:33	49° 46.99' N	39° 36.49' W	4441	4413	x		x	
49	498	2003/08/04	20:29	49° 43.45' N	38° 19.92' W	4578	4206	x	x	x	
50	499	2003/08/05	03:14	49° 40.55' N	37° 3.47' W	4360	4367	x		x	
51	500	2003/08/05	09:46	49° 36.82' N	35° 47.00' W	4250	3960	x	x	x	
52	501	2003/08/05	16:26	49° 34.05' N	34° 30.43' W	4400	4405	x		x	
53	502	2003/08/05	23:06	49° 30.44' N	33° 14.03' W	4081	4036	x	x	x	
54	503	2003/08/06	05:33	49° 26.99' N	31° 57.38' W	3590	3435	x		x	
55	504	2003/08/06	11:46	49° 24.03' N	30° 41.01' W	3598	3697	x	x	x	
56	505	2003/08/06	17:07	49° 21.98' N	29° 45.00' W	3270	3256	x		x	
57	506	2003/08/06	22:08	49° 20.09' N	28° 48.51' W	3324	3288	x	x	x	
58	507	2003/08/07	03:22	49° 18.01' N	27° 51.92' W	2824	2924		x		
59	507	2003/08/07	05:10	49° 17.76' N	27° 52.12' W	2990	2947		x		
60	507	2003/08/07	06:53	49° 17.31' N	27° 52.02' W	3020	3065		x		
61	507	2003/08/07	08:48	49° 16.59' N	27° 51.98' W	3101	3037		x		
62	507	2003/08/07	10:46	49° 16.27' N	27° 51.95' W	3064	3042	x	x	x	
63	508	2003/08/07	16:41	49° 15.99' N	26° 55.91' W	3300	1677		x		Prof. quit
64	509	2003/08/07	20:47	49° 14.02' N	26° 4.02' W	3651	3600	x	x	x	
65	510	2003/08/08	02:28	49° 47.47' N	26° 40.50' W	3544	3513	x		x	
66	511	2003/08/08	08:07	50° 20.50' N	27° 17.03' W	3833	3788	x	x	x	
67	512	2003/08/08	14:03	50° 53.99' N	27° 53.01' W	3245	3209	x		x	
68	513	2003/08/08	19:38	51° 27.50' N	28° 29.47' W	3450	3405	x	x	x	
69	514	2003/08/09	01:07	52° 0.43' N	29° 5.48' W	3810	3772	x			
70	515	2003/08/09	07:00	52° 33.98' N	29° 42.05' W	3500	3430	x	x		
71	517	2003/08/09	15:50	53° 6.95' N	30° 17.88' W	3145	3079	x		x	
72	518	2003/08/09	21:48	53° 52.49' N	30° 17.26' W	3094	3056	x	x	x	

Meteor M59/2		**CTD Stations**					**Page 3**				
Prof.	Sta.	Date	Time	Latitude	Longitude	Water Depth	Prof. Depth	Measurements CFCs	CO_2	LADCP	Comment
73	519	2003/08/10	03:47	54° 38.03' N	30° 16.37' W	3012	2969	x		x	
74	520	2003/08/10	09:28	55° 23.53' N	30° 15.96' W	2636	2548	x	x	x	
75	521	2003/08/10	14:54	55° 30.49' N	28° 58.42' W	2987	2959	x		x	
76	522	2003/08/10	20:42	55° 41.90' N	27° 38.91' W	2764	2724	x	x	x	
77	523	2003/08/11	02:17	55° 54.04' N	26° 18.88' W	3186	3160	x		x	
78	524	2003/08/11	08:09	56° 5.48' N	24° 59.43' W	3335	3313	x	x	x	
79	525	2003/08/11	14:05	56° 17.55' N	23° 37.88' W	2731	2706	x		x	
80	526	2003/08/11	19:41	56° 28.95' N	22° 19.97' W	2110	2089	x	x	x	
81	527	2003/08/12	00:48	56° 40.08' N	21° 1.62' W	1723	1705	x	x	x	
82	529	2003/08/13	07:44	54° 49.03' N	26° 18.07' W	3400	3350	x	x	x	
83	530	2003/08/13	13:48	54° 21.00' N	25° 18.54' W	2942	2919	x		x	
84	531	2003/08/13	19:41	53° 52.98' N	24° 19.00' W	3500	3443	x	x	x	
85	532	2003/08/14	01:48	53° 25.06' N	23° 19.93' W	3957	3963	x		x	
86	533	2003/08/14	08:24	52° 57.01' N	22° 20.53' W	3969	3965	x	x	x	
87	534	2003/08/14	14:52	52° 28.95' N	21° 21.49' W	3837	3834	x	x	x	
88	535	2003/08/14	21:15	52° 1.01' N	20° 22.04' W	3674	3667	x	x	x	
89	536	2003/08/15	03:25	51° 32.97' N	19° 22.93' W	4224	4251	x	x	x	
90	537	2003/08/15	10:01	51° 4.49' N	18° 23.46' W	4696	4715	x	x		
91	538	2003/08/15	17:33	50° 36.52' N	17° 24.01' W	4750	4768	x	x	x	
92	539	2003/08/16	02:15	50° 8.49' N	16° 22.97' W	4704	4723	x	x	x	
93	540	2003/08/16	09:11	49° 40.46' N	15° 25.48' W	4626	4649	x	x	x	
94	541	2003/08/16	16:07	49° 12.52' N	14° 26.48' W	4500	4519	x	x	x	
95	542	2003/08/16	23:10	48° 54.54' N	13° 17.97' W	3724	3731	x	x	x	
96	543	2003/08/17	05:40	48° 45.02' N	14° 25.62' W	4521	4542	x	x	x	
97	544	2003/08/17	12:20	48° 35.99' N	15° 32.99' W	4803	4826	x	x	x	
98	545	2003/08/17	20:10	48° 26.45' N	16° 40.52' W	4664	4657	x	x	x	
99	546	2003/08/18	03:13	48° 17.45' N	17° 47.97' W	3931	3925	x	x	x	
100	547	2003/08/18	09:39	48° 8.47' N	18° 56.09' W	4052	4056	x	x	x	
101	548	2003/08/18	16:02	47° 58.90' N	20° 2.92' W	4300	4313	x	x	x	
102	549	2003/08/18	22:41	47° 49.95' N	21° 11.08' W	4446	4460	x	x	x	
103	550	2003/08/19	04:35	47° 42.51' N	22° 3.68' W	4440	4450	x	x	x	
104	551	2003/08/19	10:31	47° 35.97' N	22° 52.04' W	4167	4161	x	x	x	
105	552	2003/08/19	15:50	47° 28.98' N	23° 41.54' W	3894	3873	x	x	x	
106	553	2003/08/19	21:00	47° 22.22' N	24° 29.44' W	3348	3288	x		x	
107	554	2003/08/20	02:09	47° 15.50' N	25° 19.93' W	2827	2815	x	x	x	
108	555	2003/08/20	08:11	47° 3.00' N	26° 23.96' W	2812	2772	x		x	

Meteor M59/2		**CTD Stations**						**Page 4**			
Prof.	Sta.	Date	Time	Latitude	Longitude	Water Depth	Prof. Depth	Measurements CFCs	CO_2	LADCP	Comment
109	556	2003/08/20	14:26	46° 49.44' N	27° 37.96' W	2411	2399	x	x	x	
110	557	2003/08/20	19:08	46° 40.04' N	28° 28.05' W	2800	2911	x		x	
111	558	2003/08/20	23:48	46° 38.51' N	29° 14.51' W	3700	3257	x	x	x	
112	559	2003/08/21	05:02	46° 37.05' N	30° 0.92' W	3400	3513	x		x	
113	560	2003/08/21	10:30	46° 35.51' N	30° 47.50' W	3431	3393	x	x	x	
114	561	2003/08/21	15:48	46° 33.98' N	31° 34.01' W	3764	3726	x		x	
115	562	2003/08/21	21:55	46° 32.51' N	32° 20.94' W	3999	4002	x	x	x	
116	563	2003/08/22	03:35	46° 30.95' N	33° 7.47' W	3873	3844	x		x	
117	564	2003/08/22	10:00	46° 33.48' N	34° 9.41' W	4285	4278	x	x	x	
118	565	2003/08/22	16:49	46° 36.95' N	35° 8.47' W	4365	4337	x		x	
119	566	2003/08/22	23:38	46° 41.02' N	36° 7.09' W	4155	4126	x	x	x	
120	567	2003/08/23	06:16	46° 44.49' N	37° 5.93' W	4590	4554	x		x	
121	568	2003/08/23	13:31	46° 48.40' N	38° 4.84' W	4563	4470	x	x	x	
122	569	2003/08/23	20:52	46° 51.96' N	39° 3.90' W	4588	4587	x		x	
123	570	2003/08/24	04:02	46° 55.47' N	40° 2.88' W	4560	4552	x	x	x	
124	571	2003/08/24	08:41	46° 57.04' N	40° 30.57' W	4550	4540	x		x	
125	572	2003/08/24	14:52	47° 0.12' N	41° 25.59' W	4360	4326	x	x	x	
126	573	2003/08/24	19:17	46° 59.06' N	41° 1.99' W	4500	4488	x	x	x	
127	574	2003/08/25	00:20	47° 0.08' N	41° 37.62' W	4291	1204	x	x	x	bad data > 1200 m
128	575	2003/08/25	04:25	47° 0.03' N	41° 48.99' W	4250	4215			x	
129	576	2003/08/25	07:49	47° 0.01' N	42° 3.54' W	4220	4168	x	x	x	
130	577	2003/08/25	11:30	46° 59.98' N	42° 14.00' W	4086	4047			x	
131	578	2003/08/25	14:43	47° 0.03' N	42° 24.05' W	3900	3860	x	x	x	
132	579	2003/08/25	18:37	47° 0.01' N	42° 34.49' W	3800	3686			x	
133	580	2003/08/25	21:56	47° 0.00' N	42° 45.50' W	3613	3568	x	x	x	
134	581	2003/08/26	01:08	47° 0.02' N	42° 55.09' W	3647	3483			x	
135	582	2003/08/26	04:05	46° 59.96' N	43° 3.39' W	3346	3385	x	x	x	
136	583	2003/08/26	07:25	46° 59.97' N	43° 11.48' W	3000	3116			x	
137	580	2003/08/26	09:33	46° 59.34' N	43° 11.58' W	3133	2934			x	
138	583	2003/08/26	11:35	46° 58.12' N	43° 11.86' W	2626	2566	x	x	x	
139	584	2003/08/26	14:28	47° 0.12' N	43° 15.02' W	2242	2033			x	
140	585	2003/08/26	16:17	46° 59.99' N	43° 20.02' W	1513	1475	x		x	
141	586	2003/08/26	19:02	47° 0.04' N	43° 24.37' W	1500	1211	x		x	
142	587	2003/08/26	20:33	46° 59.94' N	43° 30.44' W	990	961	x	x	x	
143	588	2003/08/26	22:07	47° 0.03' N	43° 40.46' W	765	737	x		x	
144	589	2003/08/26	23:48	47° 0.01' N	43° 55.44' W	482	460	x		x	

List of Participants M59/2

Monika Rhein	IUPHB	chief scientist
Samuel Acquah	IUPHB	CTD
Tim Fischer	IFMK	CFCs
Karsten Friis	IFMK	CO2
Sabine Graf	IUPHB	CTD, CFCs
Susann Grobe	IFMK	CO2
Gerhard Kahl	DWD	meteorology
Dagmar Kieke	IUPHB	CFCs
Jochen König	IFMK	CTD, mooring
Britta Kührig	IUPHB	CTD
Jan-Olaf Krisponeit	IUPHB	CTD
Frank Malien	IFMK	nutrients, O2
Christian Mertens	IUPHB	vm-ADCPs
Zeljko Novak	IFMK	CFCs
Philip Nuß	IFMK	CO2
Wolf-Thilo Ochsenhirt	DWD	meteorology
Hendrik Sander	IUPHB	CTD/LADCP
Sandra Schröder	IUPHB	CTD, mooring
Martina Schütt	IFMK	CFCs
Reiner Steinfeldt	IUPHB	CTD,O2, calibration
Tobias Steinhoff	IFMK	CO2
Jenny Ullgren	NUIG	CTD
Maren Walter	IUPHB	LADCP

DWD
Deutscher Wetterdienst, Geschäftsfeld Seeschifffahrt, Bernhard-Nocht-Str. 76, 20359 Hamburg

IUPHB
Universität Bremen, Institut für Umweltphysik, Abt. Ozeanographie, Otto-Hahn-Allee, Gebäude NW1, 28359 Bremen

IfMK
Institut für Meereskunde an der Universität Kiel, Düsternbrooker Weg 20, 24105 Kiel

NUIG
National University of Ireland, Newcastle Road, Galway, Republic of Ireland