NERSC Technical Report No. 147

ESOP2 winter cruise

in the Greenland Sea with R/V Håkon Mosby

4-31. March, 1998

Cruise Report

This work is part of the ESOP-2 and the IMCORP projects supported by the MAST Programme of the European Union (MAS3--CT95--0015 and MAS3--CT95--0023)

written by

**Knud Simonsen^1, David Cooper^1, Ute Schuster^1,2
Mats Bentsen^1, Frank Cleveland^1, Jonathan Delaney^4,2
Cathrine Netland Egset^3, JoAnne Kruepke^5, Are Olsen^2,
Abdirahman M. Omar^2, and Fredrik Svendsen^3.**

**^1 Nansen Environmental and Remote Sensing Center, Norway
^2 Center for Environmental and Resource Studies, Norway
^3 Geophysical Institute, University of Bergen
^4 School of Environmental Sciences, University of East Anglia, UK
^5 University of Wisconsin, USA**

Nansen Environmental and Remote Sensing Center, Norway

This is contribution no. 18 from G. C. Rieber Climate Institute at NERSC.

Introduction

The scientific activity on this cruise are part of two EU MASTIII funded projects, European Sub-Polar Ocean Programme, Phase 2 (ESOP2) and Instrumentation for Marine Carbon Dioxide from Remote Platforms (IMCORP). In addition a current meter mooring is deployed as part of the Regional Climate project financed by the Norwegian Research Council. The data collected during this cruise will be included as a contribution to the JGOFS programme.

European Sub-Polar Ocean Programme, Phase 2

The general accepted understanding is that relative warm and saline water from the West Spitzbergen Current is entering the Greenland Sea, and cold and fresh water is entering from the Arctic Ocean. In the Greenland Sea the water cools during winter, and the salinity may increase as a result of brine rejection, both processes leading to formation of denser water masses. If the surface water becomes sufficiently dense, the water may mix down to great depths. The dense and intermediate to deep water masses then spill over the ridges between Scotland and Greenland and contribute to the renewal of the abyss waters of the world oceans.

The northward flow of warm water into the Nordic Seas and the subsequent release of heat to the atmosphere contribute greatly to the relatively mild climate in northern Europe. However, paleo-climate reconstructions show that the climate has undergone regular long periodic cycles between glacial and interglacial phases. These major fluctuations in the climate system of the Earth may partly be explained by changes in the Solar insolation. However, abrupt changes on time scales less than a century are frequently explained by reduction or even shut down in the deep water convection in the Nordic Seas. The underlying processes involved in the deep water production are, however, poorly understood.

The overall task in the European Sub-Polar Oceans Programme, phase 2 (ESOP2) is to study the thermohaline circulation in the Greenland Sea in order to provide a better understanding of the processes causing deep water formation. The project includes sub-projects on physical oceanography, ocean carbon chemistry, and ocean and sea-ice modelling.

The field activities of the ESOP2 project are built around the new technique of deep-sea tracer release using sulphur hexafluroide (SF6). The tracer release experiment, together with measurements of the other tracers in combination with various hydrographic measurements, provide a uniqe opportunity for the modelling community to validate the ocean models on their ability to simulate the physical processes in the region. Vice versa, the modelled fields and the derived quantities will be used to understand the dynamics of the processes in the region, and thus add valuable information to the measurements.

The tracer was released during the cruise with the British research vessel R/V James Clark Ross in August, 1996 (Watson, 1996). 320 kg was injected at the depth of the 28.049 sigma_theta density surface, which was at about 240 m depth in the central gyre and decending to about 450 m in the outskirt of the release area. Since then the spread of the tracer has been documented on cruises with R/V Håkon Mosby [Simonsen et al, 1997b, 1997c], R/V Johan Hjort and R/V Polarstern in the Greenland Sea, and north of Iceland samples has been sampled on the quertarly cruises with R/V Bjarne Sæmundarsson (Jansen and Opheim, 1997). This cruise is the third cruise with R/V Håkon Mosby in the Greenland Sea dedicated to tracer hunting. One of the main aims on this cruise is to map the extension of the tracer patch, i.e. to document the horizontal and vertical spread in the central part of the Greenland Sea.

Another aim of the ESOP2 project is to make a substantial contribution to the understanding of high latitude carbon cycle. On this cruise measurements of carbon cycle parameters throughout the water column and continues measurements of the sea surface waters were performed.

Instrumentation for Marine Carbon Dioxide from Remote Platforms

The marine carbon dioxide cycle plays an important role for example in the buffering of the anthropogenically caused increase of atmospheric carbon dioxide, but scientific knowledge about it is of date still limited. The carbon dioxide system can be characterized by measuring two of the four parameters: pH, pCO2 (partial pressure of carbon dioxide), TCO2 (total carbon dioxide) and TA (total alkalinity).

In order to be able to increase the data sets collected for the marine carbon dioxide cycle, within the

IMCORP project, automated instrumentation (called the VOS system) is being developed, which analyses surface seawater pCO2, TCO2, and pH, as well as marine air pCO2. It is designed to be a turn-key instrument which runs unattendedly whilst deployed on board ships, both scientific and merchant. This prototype has been developed by the University of East Anglia (UK) and is being field-tested by the SMR group at UoB. The instrument was deployed on board R/V Håkon Mosby for its second sea trial in order to determine its performance in terms of analytical accuracy and precision under ship-board conditions, and in terms of its abillity to run in an automated/unattended mode for long periods of time.

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Scientific party and crew members

The members of the scientific party are listed in Table 1, along with their responsibilities, and the members of the crew are listed in Table 2.

Table 1. The scientific party

Name	Afiliation	Responsibilities
Knud Simonsen	NERSC	Hydrography, Chief Scientist
Mats Bentsen	NERSC	Hydrography
David Cooper	UoW/PML	SF6, PI
JoAnne Kruepke	UoW	SF6
Fredrik Svendsen	UoB	O2 and Salinity
Ute Schuster	UEA/UoB	Carbon chemistry, PI
Abdirahman M. Omar	UoB	Carbon chemistry
Are Olsen	UoB	Carbon chemistry
Jonathan Delany	UEA/UoB	Carbon chemistry
Frank Clevelnad	UoB	O2, Salinity, Carbon chemistry
Cathrine Netland Egset	UoB	O2, Salinity, Carbon chemistry
Abbreviations		
	UEA	University of East Anglia, UK
	UoW	University of East Winconsin, USA
	SMR	Center for Environmental and Resource Studies, Norway
	NERSC	Nansen Environmental and Remote Sensing Center, Norway
	UoB	University of Bergen, Norway

Table 2. Crew

Name	
Ole Magnus Røttingen	Master

Jarle Vedholm	Mate
Bjørn Skaar	Chief Engineer
Bjørn Stensønes	Boss
Jan Kåre Østervold	Seaman
Karl Brattholmen	Seaman
Asgeir Steinsland	Instrument Engineer
Trygve Kåre Byrknes	Stuert
Rita Evelyn Bertelsen	Stuert Ass.

Summary of the tracer and hydrographic observations

by Knud Simonsen

This cruise of 25 days was favoured by relatively good weather, and close to optimal ice conditions. The weather prevented measurements in only 6 days, in addition to a return 2 days earlier than scheduled. Malfunctioning CTD, and following repair, as well repair of meter wheel in the gantry block and of the frame protecting the rosette cost approximate 5 days. Some of the damages are most likely partly due to periods of sampling in harch weather (14-20 m/s), where the conditions were close to the limits of measurment operations. The relative favourable conditions, however, are reflected by a Snumber of measurements and station, which are well beyond the expectations prior to the cruise.

On this cruise 78 CTD casts have been done; 67 to full depth, of which 38 are to more than 3000 m depth, 6 casts to 2000 m at positions with deeper bottom depths, and at 5 positions are additional casts done down to 600 m in order to collect more water samples. The accumulated water column measured by the CTD is 208,544 m, exclusive casts when the CTD has failed. Those more than 417 km of wire has passed through the meter wheel during this cruise. 936 bottles are fired, but due to not closing bottles, damaged bottles, etc., the number of samples is somewhat less. For some parameters samples were only drawn at selected depths. In addition a current meter mooring was deployed on the sill in the Jan Mayen Channel right north of Jan Mayen as part of the national Regional Climate project. The position of each station is showed in [Figure 1].

Three sections across the Greenland Sea Basin with nearly all stations are to full depths provide a fairly good documentation of the large scale circulation in the area. The sampling is however to coarse to document small scale activities. Although some regional variations, sharp gradients in temperature and salinity were found at 200 m and at around 500 m, indicating a 'two layer' surface layer. The deeper part of the basin was characterized by a temperature maximum around 1500 dbar depth, wich also marked the upper gradient to a salinity maximum of about 34.906, relative to the salinities of about 34.900 found at the bottom deeper than 3000 m. Along the Greenland slope between 1300--2500 dbar slightly more salinie and warmer water masses, which fits the classic characteristics of Euroasian Basin Deep Water, was evident in all three sections. Above the upper part of the slope just beneath a shallow layer of fresh and cold meltwater observations were made of water with Atlantic Water characteristics.

The SF6 patch seems to cover the entire Greenland Sea basin at, or close to the density surface were it was deployed in 1996. Along the western border of the survey area at the East Greenland slope, the concentrations were low and seemed to tail off towards the slope at those depths of density where the SF6 was originally deployed. To the east, the patch was found to tail off along the Mohn and Knipovich Ridges, although we can neither confirm nor reject that there might be places where the SF6 is entering further east into the Norwegian Sea. (Figure 10)

Along the 74° 30'N section high concentrations were found in the western part of the basin, as in previous cruises. Although apparently favourable ice conditions would have allowed us to go further south into North Bukta, bad weather weather prevented measurements both times we were in the area. However, based on the traditional picture of the circulation it is assumed that the patch continues southward to the Jan Mayen Fracture Zone. This is partly confirmed by measurements showing concentrations above background values in the Jan Mayen Channel west of the sill in the channel right north of Jan Mayen island with the highest concentrations above the southern slope of the channel at 800-1100 m depth. Observation of SF6 east of the sill documents an eastward flow at intermediate depths through the channel. However, as mentioned earlier this may not be the only path way of intermediate water from the Greenland Sea into the Norwegian Sea, which is indicated by the findings of SF6 at the same depth at St. 7 just north of the JMC, and the other stations above the Mohn and Knipovich Ridges further north. It may be noted that the the highest SF6 concentrations are found at the depth of the density surface were the tracer was deployed.

Relative high concentrations of SF6 was found close to the surface at the majority of the stations. In addition leaking to the atmosphere is also documented by measurement of relative high concentrations in air samples. At several positions the mixed layer reached to 300-500 m depth, or just above the maximum concentrations in the patch. It seems likely that the mixed layer has penetrated into the patch at least at some locations, and those the SF6 is brought to the surface.

The SF6 seems to continue northward with the extension of the Jan Mayen Current into the Boreas Basin, as documented already by the observation made on samples collected by R/V Polarstern in Sept., 1997. Documentation of the further fate of the north going branch of the SF6 was not done north of the 76° 00' N latitude, partly due to southward retreat due to bad weather, and partly because high priority was put on sampling in the eastern Greenland Sea. One station was however taken at 76° 30'N, 01° 00'W, i.e. on the northern flank of the Greenland Sea Fraction Zone, which showed relatively low concentrations of SF6 around the target density.

In the vertical the SF6 is in general seen in the upper 1200-1500 m of the water column although the major concentrations are found around the target density. An observation is that the upper limit of the SF6 patch is in slightly lighter water in the central Greenland Sea than in the eastern part of the basin.

Slightly higher than background concentrations were found along the bottom in the Greenland Sea Basin at all three main sections. Along the 74° 30'N section no SF6 was found east of 2° 00'W along the bottom.

On the second leg of the Feb-March cruise with R/V Håkon Mosby in March 1997 [Simonsen et al 1997a, 1997c] in the area last year descending fresh and cold surface water was observed almost in action along the ice edge almost in action. The remnants from this event are still evident as a low saline and slightly colder bulge of water extending from about 500 m to about 1200 m depth 3° 30'W and 5° 30'W (Figure 3). However, more recent 'refill' of the bulge from the surface can not be excluded from the data. Moreover, the bulge of freshwater coincide with a local patch of SF6 (Figure 10). One possible mechanism for the occurrence of this SF6 patch is that it has followed the freshwater on its way down from the surface, and another alternative is that it has been advected along the disturbed isopynals into its present positions. However, it must be stressed that any analysis in any detail has no been done yet, and the speculations above must be taken with some caution.

In summary this cruise has provided a good description of the horizontal and the vertical spread of the SF6 patch, and also an extensive mapping of the hydrographic parameters in the area. In addition to the parameters mentioned above, this cruise all provides a similar good horizontal and vertical coverage of oxygen isotope and various carbon cycle parameters. The equipment to measure underway surface pCO2, TCO2, pH, SST, and meteorological data has functioned during the entire cruise. The data collected during this cruise is fully documented in the following sections.

Figure 1. Cruise track and CTD stations.

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Diary

by K. Simonsen

04.03.98: Installed our equipment onboard. Left Marineholmen at 19.00 (local time) and went to Skarvholmen just outside Bergen where bunkers were taken. At Skarvholmen a rescue exercise were conducted. There after a testcast was done in Byfjorden, and at midnight we went to Bergen to bring Ingunn Skjelvan, Solveig Kringstad and Richard Bellerby from SMR on land. They have installed some of the gear in the laboratories. Shortly after we headed towards Jan Mayen.

05.03.98: Heading towards Jan Mayen. The weather is changing and occasionally we have snow showers with gusty winds.

06.03.98: Windy, up to 25 m/s right in the front. At times slow speed. The icemaps, which we receive from Danish Center for Remote Sensing in cooperation with Danish Meteorological Institute , shows that the Odden ice features seems to grow again. Allmost the entire target area was ice covered earlier this winter, but a storm between 25'th and 26'th of February removed most of the ice in the Greenland Sea. Since then the ice conditions has been very favorable, but it seems to change now.

07.03.98: Quite windy and heavy waves early this morning, but calm and nice weather in the afternoon. The Odden is still growing

08.03.98: Put out a current meter mooring in the Jan Mayen Channel on position 71° 10.7'N; 7° 40.6' W this morning. This is part of the Regional Climate project financed by the Norwegian Research Council. The results from these measurement is however interesting for the ESOP2 project as well. Sampled 4 station along 8°00' W across the JMC. Although some initial problems like misfiring of water sampling bottles and leaking tubes on the CTD sonde, good hydrographic data was obtained from at least one of the sensor set at all these stations. Found relative high SF6 concentrations (3-6 fmol/l) between about 700 to 1200 m, in particular above the southern slope, and also quite high values (2-7 fmol/l) in top 400 m. In order to see if the tracer had passed the sill in the JMC, a station was done in the basin just east of the sill. At this station relative high concentrations were found around 800--1000m, which indicate that some intermediate outflow from the Greenland Sea at this depth. The weather today has been from nice to quite gusty with winds up to 18 m/s in the snow showers. The weather forecast for tomorrow is not good, strong gale to storm from north east.

09.03.98: Passed light pancake ice at 72°53'N, 3°15'W this morning, and at 73°00'N, 3°00'W we went into relativity high concentrations of pancake ice with a diameter of 50-100 cm, - sometimes slightly larger. Sampled eastward along the 73°00'N latitude to 4°00'E. After this station the wind increased considerably and further sampling was not possible.

10.03.98: Heavy waves and 18-22 m/s wind from NE and occasionally snow showers. No sampling activity.

11.03.98: Weather is as yesterday. Due to the comfort onboard we give up to start sampling at 75° 00' N, 6° 00'E, and are moving slowly westward with the weather. Aims to start at 75° 00' N, 0° 00' E, and to sample the heastern part of this section later on the cruise. Went into pancake ice at about 74° 25'N, 2° 00'E. Was in contact with R/V Johan Hjort. If they will not be delayed early in their cruise, they will take a hydrographic section through the Greenland Sea. According to the rumors is {\em R/V Jan Mayen} from the University in Troms{\o} on the way to the Greenland Sea as well. Seems to be crowdy up here. Just before midnight the wind decreased, but the waves are still high.

12.03.98: Start sampling this morning at 75°00'N 0°00' E. The waves were still heavy, and the conditions were close to the limit for the equipment. Later on the day the sea become calmer. Find SF6 between 400 m and 1000 m, with the maximum close to the target density at about 500-700 m. Today we also found out, that the Niskin bottles were mounted the wrong way around on the rosette. The sampling numbered 1 to 12 resulted in a sampling sequence of the Niskin bottles as follows: 1,12,11,...., 3, and 2. The numbering of all samples so far were corrected imediately after the discovery of this blunder. Started to take double stations at some positions in order to get better sampling density in the vertical. The first cast is to 650 m, and the second is to the bottom with water samples from the bottom to 700 m. Was in contact with R/V Johan Hjort. They are working along the Bear Island section, and are more than two days behind the schedule due to bad weather. Most likely, they will not have time to sample into the Greenland Sea as planned.

13.03.98: Wonderful weather, but the primary sensor start failing this night at St. 21. Checked connections, but it didn't help. At St. 23 we noticed that also the secondary sensors are malfunctioning. Changed sensors, terminated the cable, adjusted the winch, and finally we were back in business again. In order to reach the ice in the west before dark, we were going full speed westward while these repairs were done and started sampling again at 8° 00'W and continued to 10° 00'W along 75° 00'N, where we stopped sampling along thie section because of the darkness and heavy snow showers. Continued southward to 74° 30'N along the 10° 00'W meridian. In addition the freshwater generator brokened. The chief engineer is working on it, but he is not sure that he have all required spare parts. If he do not succeed, the last laundry is done on this cruise. Who mentioned Friday the 13'th.

14.03.98: Did one station at 74° 30'N, 10° 00'W , and headed westward when the daylight began and reached to 13° 00'W in open water. Passed only some small ice pieces along this path. Some of the participants were quite disappointed, because the expected to see some real ice here. Sampled eastward along 74° 30'N during the day. The fresh water generator is fixed and works excellent again, which is a releasing news for those who have not done their laundry yet. The weather forecasts are inconsistent for the following day. Some forecasts says wind of strong gale, while other forecasts only expect up to strong breeze.

15.03.98: Passed a stripe of ice floes just before station 33. Some problems to measure alkalinity in the lab. The weather forecast says full storm later today. The pressure suddenly dropped 9 mb to 971 mb, but raised again to 973 mb. The wind increased to 17 m/s, but then it decreased again. We are staying in the pan-cake ice, which damps the waves, and continue working as long as possible. Ended the 74°30' section at 4°00'W, and continued to 75°00' N to fill in the gap we left in that section a couple of days ago.

16.03.98: Managed to get the ADCP operational for the first time on the cruise. A new more accurate position and velocity estimator, Seapath, is recently installed, which among other instruments also will feed the ADCP with navigation data. Unfortunately, the ADCP has only been tested when using bottom tracking since the Seapath was installed, and it turned out not to be operational when it was switched to navigational mode. However, from today the ADCP is operational in navigational mode also. From 75°00'N 7°00'W we start sampling a section normal to the continental slope heading towards 76° 00'N 9° 00' W. Went into ice at 75° 57' N, 8° 30' W, at stopped for St. 43. At this position we were surrounded by pancake ice, and the radar indicated that older ice was just north of us. The weather condition were rough, -20° C in the air, wind of 11 m/s, and dense freeze smoke. However, already at 100 m depth the temperature was above zero degree Celsius, and at 500 m the temperature exceeded 1° C. Just before the CTD reached the bottom the ice north of us begun to drift toward our position. In order to get the CTD up quickly, the normal procedure of waiting at least 30 sec. at depth were the bottle is to be fired was skipped, and it was only stopped for the time needed to fire the bottle. When the CTD was at about 50 m depth a piece of ice followed the wire into the emergency stopper, the heaving of the CTD stopped and caused some active minutes in the CTD--room. However, we left the area in due time before the ice reached us, but we had to leave the area in SSE direction until we passed 7°45'W, at 75° 45'N, because a ice bridge prevented the passage in right western direction. Continue sampling along 76° 00'N.

17.03.98: Sampled along 76° 00'N. Found a freshwater bulge at 800--1200m between 6° 00'W and 4° 00' W, which most likely is the remnants of the descending fresh water observed in the March-97, Leg2 cruise in the area. However, later supply of fresh water from the surface to intermediate depths can not be ruled out.

18.03.98: Early today the CTD striked due to bad connection between the wire and the instrument, and partly due to some intrusion of water into some of the contacts. Used 5 hours before it was ready for operation again. Planned to sample along the northern flank of Greenland Fraction Zone in order to find if the tracer has reached that far north, but bad weather with wind up to 26 m/s came in and we had to stop the sampling.

19.03.98: Bad weather this morning, but after lunch we start to sample again westward along 76°00'N. However, the weather condition, 13--17 m/s, is just on the limit for doing CTD casts.

20.03.98: Finished the 76° 00' N section at 7° 00'E, and started to sample along the 75° 00' N latitude at the same longitude. The weather has become nice and there was some expectations that this section would be quickly done. But, on the way down at about 800m depth at the next station in the section (St. 62) we lost the contact to the CTD, and the CTD was taken on deck again. Back on deck it was also discovered that the frame protecting the rosette and CTD was broken. These damages were repaired and a second attempt to complete this station was done. Observation of a minky whale was reported from the bridge.

21.03.98: The CTD system worked fine in the second attempt to complete St. 62, but two Niskin bottles were imploded, and one had disappeared (bottle positions 10, 11, and 12). Several people checked that the rosette was as it should be before it was launched into the sea, so the most likely explanation for the implosion is that the bottles has closed when they hit surface or just after. Since only one 10 l sparbottle was left, two 5 l bottles were mounted. On St. 63 the newly mounted bottles didn't close, but some water was in the bottle position 12, which was used for SF6 analysis. St. 64: Lost the communication with the CTD just after the first bottle was fired. Spent most of the day, performed three test casts before the CTD was operative again.

22.03.98: Sampled southward along the 3° 00'W meridian. The plan was to do a station at every 15', but due to bad weather forecast this plan was skipped in order to move southward more quickly. The ice conditions are again about to be very favorable in order to go south into the Nord Bukta, and this option is under consideration.

23.03.98: The weather forecast at last midnight informed about an intense low-pressure coming north from Iceland along the coast of Greenland. At midnight the center was at 72° 00'N 10° 00'W, and full storm NW of Jan Mayen. We are moving east in an attempt to avoid the bad weather as long as possible.

24.03.98: Continue eastward along 74° 30' to 5° 00'E, and then toward 73° 00'N 7° 00'E. The hope was to document the tailing of into the Norwegian Sea, but the weather become to bad before we reached the 73° 00', 7° 00'E. Continue slowly to 72° 00'N, 8° 00'E, but the weather is still bad. The weather forecast along the coast is bad as well, so it seems we had to wait a day or two before we can do the next station. Since we only have two days left in the area, and the chances to do more stations are small, we start our journey back to Bergen. This first day of the transit back to Bergen was quite uncomfortable with wind of 16-20m/s right in the front and heavy swells. Are heading to Andøya in the Lofoten Islands, and then along the coast to Bergen. The Seapath stopped functioning, which caused brake down in the ADCP as well, since the Seapath is feeding it with navigation information.

25.03.98: Passed And{\o}ya this afternoon, and continue southward along the coast.

26.03.98: Still heading southward along the coast.

27.03.98: Heading southward.

28.03.98: Docked in Bergen early this morning.

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Water sampling and performance of the CTD

by F. Cleveland and C. N. Egset

Water samples were drawn from the Niskin bottles immediately the rosette was on deck. The sampling order of water to the various parameters is listed in Table 3.

Table 3. Sequence of the water sampling

No	Variable	Frequency
1	SF6	All depths

2	O2	5-8 samples at selected depths
3	DIC	All depths
4	d13C	5-8 samples at selected depths
5	Nutrients	All depths
6	Alkalinity	All depths
7	d18O	5-8 samples at selected depths
8	Salinity	5-8 samples at selected depths

Listed below are anomalies from normal procedure and failures encountered during the course of the cruise:

St. 2. All the 12 Niskin bottles were fired at 1905 m. depth. Primary sensors failed.

St. 3. Secondary sensors failed due unconnected pipes.

St. 4. The d13C samples from this station was not poisoned. Alkalinity was tapped after the d18O.

St. 5. Niskin bottle 1 did not close. No samples from 2100 m. depth. Alkalinity samples CARDEEP No 6664 and 6665 from station 5 is missing. Primary sensor failed due to loose pipes.

St. 8. Niskin bottle 5 did not close.

St. 10. Niskin bottle 5 did not close.

St. 13. Niskin bottle 5 did not close.

St. 15. Niskin bottle 12 did not close. It was discovered that the numbering of the bottles were inconsistent with the firing sequence, and those caused confusing about the sample numbering. All sample numbering is however corrected to follow the firing sequence in this report. For all later stations the bottle number followed the firing sequence. The bottle numbers and firing sequence for stations 2--15 is listed below.

Firing sequence	Bottle number
1	1
2	12
3	11
4	10
5	9
6	8
7	7
8	6
9	5

10	4
11	3
12	2

St. 16.Niskin bottle 5 did not close.

St. 18. Primary sensors noisy in the top 500 m.

St. 20.Alkalinity was collected in wrong order, CARDEEP No 6840 was collected from Niskin bottle 6 at 1800 m, and 6839 was collected from bottle 7 at 1600 m. Primary sensor failed.

St. 21. Primary sensors failed.

St. 22. Primary sensors failed.

St. 23. Primary sensors failed. Gave up to fix the primary sensors and replaced the temperature (T1692) and conductivity (C1399) sensors with the sensor set numbered T1598 and C1337, respectivily. CTD cable terminated.

St. 24. Wrong conductivity on primary sensor due to mistyping of calibration coefficient.

St. 25.Niskin bottle 5 did not close.

St. 26. Primary sensors quit noisy between 500 m and 700 m both on down- an up casts.

St. 28.Niskin bottle 5 did not close.

St. 31.Niskin bottle 5 did not close. Alkalinity was not sampled at this station.

St. 33.Niskin bottle 6 was fired at the same depth as bottle 5.

St. 36.Niskin bottle 8 did not close.

St. 38. The meter wheel malfunctioned at 3400 m. Caused a stop at this depth on the downcast. Niskin bottle 8 did not close.

St. 40.Alkalinity sample CARDEEP No 7074 is missing. Niskin bottle 1, 3350 m.

St. 44.Niskin bottle 5 did not close.

St. 48.Niskin bottle 5 did not close.

St. 49.Only SF6, O2 and Salinity are sampled.

St. 51. No CTD-data logged electronically, but T, S, and P at water sample depths are logged manually.

St. 54. The estimated wire length by the meter wheel has been non--regular since St. 38. Replaced with the meter wheel in the other gantry block just before this station.

St. 56. The samples of d13C and d18O are missing, - they were washed away into the sea. CARDEEP No 7254 to 7265.

St. 57.There are no tops left for d13C and d18O samples, which ends the collection of these samples. CTD cable terminated. Discovered damages on the CTD frame, which was repaired -preliminary.

St. 62.Niskin bottles 10, 11 and 12 imploded. A 10 l Niskin bottle was mounted in position 10, and 5 l Niskin bottles in positions 11 and 12.

St. 63. Niskin bottles 10, 11 and 12 did not close. Meter wheel start cheating again.

St. 64.Only Niskin bottle 1 was fired. Lost connection with the CTD at 2785 m on the upcast. Changed contacts and cables on the CTD and terminated the cable.

St. 68.Only SF6, O2 and Salinity was sampled.

St. 69.Niskin bottle 10 did not close.

St. 71.Alkalinity was sampled from Niskin bottles 1 (CARDEEP No 7411), 6 (7416) and 10 (7420).

St. 74.Niskin bottle 5 did not close. More damages on the CTD frame.

St. 75.Niskin bottle 12 did not close.

St. 79.Niskin bottles 10 and 12 did not close.

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CTD measurements

by K. Simonsen and M. Bentsen

CTD--instrument

The CTD was a SBE 911plus from SeaBird Electronics equipped with dual salinity, temperature and oxygen sensors in addition to a pressure sensor. One set of the temperature, salinity and oxygen sensors was purchased in Sept., 1996, and are dedicated to the ESOP2-cruises. The other set of sensors, as well an extra set, belongs to the standard equipment on the research vessel. The time of the last calibrations of the temperature and salinity sensors is listed in Table 4 and of the used oxygen sensor is listed in Table 5 in additon to the respective calibration coefficients. The pressure sensor was calibrated 05.05, 1994, but passed a stability test at the manufacturer the 07.01, 1998.

The standard equipment on the vessel is a SeaBird 12 bottle rosette with 10 l Niskin bottles mounted on a 6000 m long 6.4 mm thick wire. The sampling and initial processing of the data was done on a personal computer (PC) dedicated to this purpose using the software provided by the CTD--manufacturer. The second step was to transfer the data to a workstation for further analysis and visualization. During the course of the cruise electronic measurements of salinity was compared to analysis of water samples. The final processing including calibration of the data will be done posterior to the cruise.

Table 4. See paper copy.

Table 5. See paper copy.

Data collected

During the cruise 78 CTD casts has been done; 67 to full depth, of which 38 are to more than 3000 m depth, 6 casts to 2000 m, and at 5 positions are additional casts done down to 600 m in order to collect more water samples. At St. 3 the secondary sensor failed due to disconnection of the water pipes to the pumpes, and at some stations the primary sensor failed either due to disconnections of the pipes, or due to malfunctioning of the sensors. Details may be found in Sections Diary and Sampling or in the stations summary table (Appendix I). The primary sensors were replaced with new sensors after St. 23. Except for St. 51 data of acceptable quality was logged with at least one sensor set at all stations. At St. 51 no data was logged due to erroneous position of a switch. Comparison of CTD measured salinity with salinometer analyzed water samples shows that the secondary sensor set has been quite stable during the cruise (Figure 5). Final processing and calibration will be done posterior to the cruise. Here an apparently constant bias equal to 0.00122 for the secondary salinity 'sensor' relative to the salinometer analyses is subtracted from the salinity if nothing else is stated. One the following pages are the data collected with sensor set two presentedand. In the theta-S-diagrams presented the major specific deep water masses given in Table 6 are indicated.

Table 6. Definition of some major water masses included in the theta-S-diagrams.

Water mass	Definition	Source	Indication
NSDW	34.908 < S < 34.911; -1.06C < theta < -0.93C	Swift et al, 1983	box
NSDW	S = 34.910; theta= -1.048C	Swift and Koltermann, 1988	circle
GSDW	34.88 < S < 34.90; -1.29C < theta < -1.0C	Summary of previous definitions	box
GSDW	S = 34.899; theta= -1.149C	Bonisch et al, 1997	circle
AODW	34.919 < S < 34.936; -0.96C < theta < -0.70C	Swift et al, 1983	box
EBDW	34.92 < S ; theta < -0.8C	Rudels and Quadfasel, 1991	circle
UPDW	34.90 < S < 34.92; -0.5C < theta < 0C	Rudels and Quadfasel, 1991	box
NSDW	Norwegian Sea Deep Water		
GSDW	Greenland Sea Deep Water		
AODW	Arctic Ocean Deep Water		
EBDW	Eurasian Basin Deep Water		
UPDW	Upper Polar Deep Water		

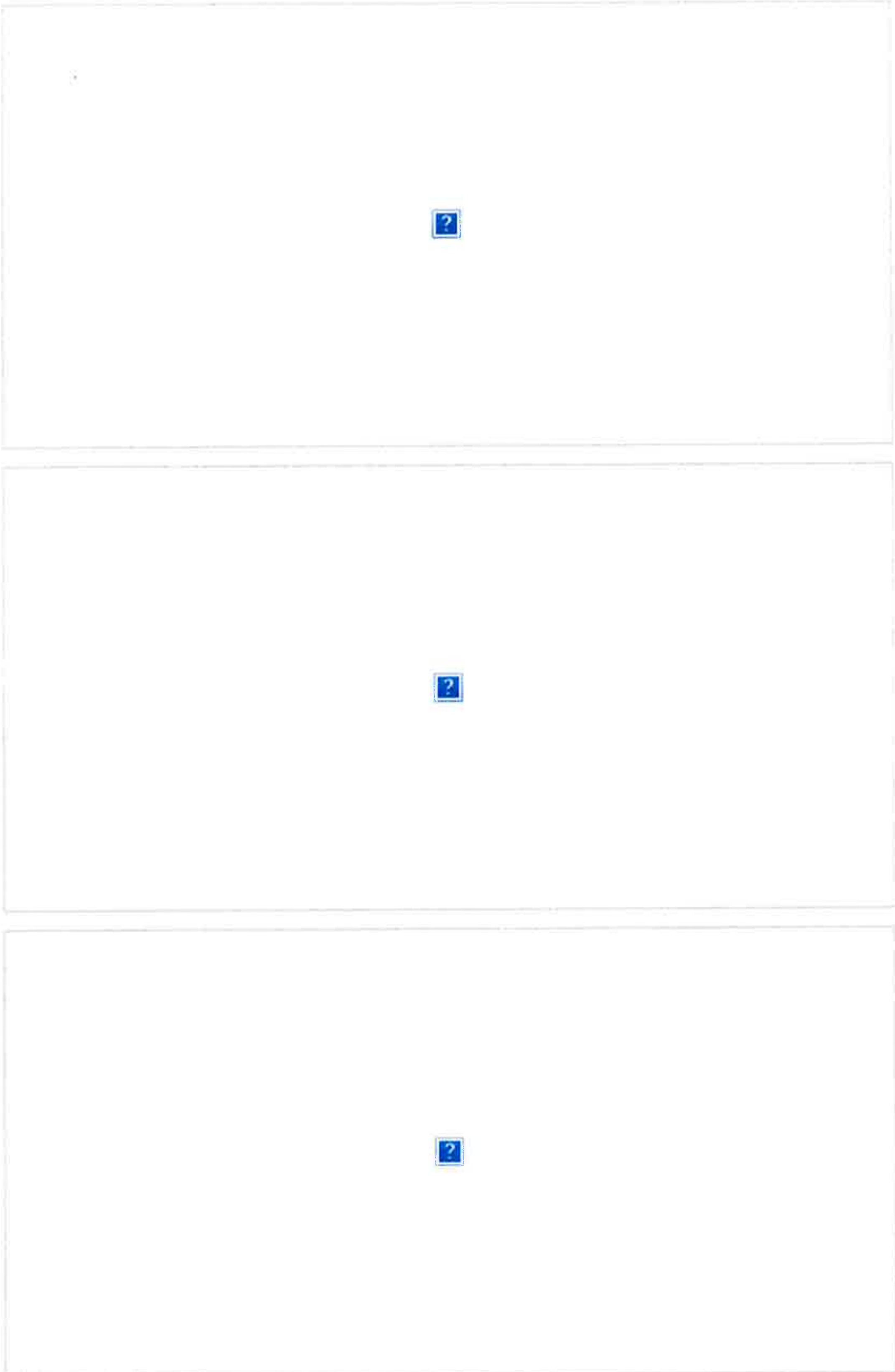


Figure 2. theta (top), S (middle), and σ_{theta} (bottom) along 76° 00'N. Uncorrected data.

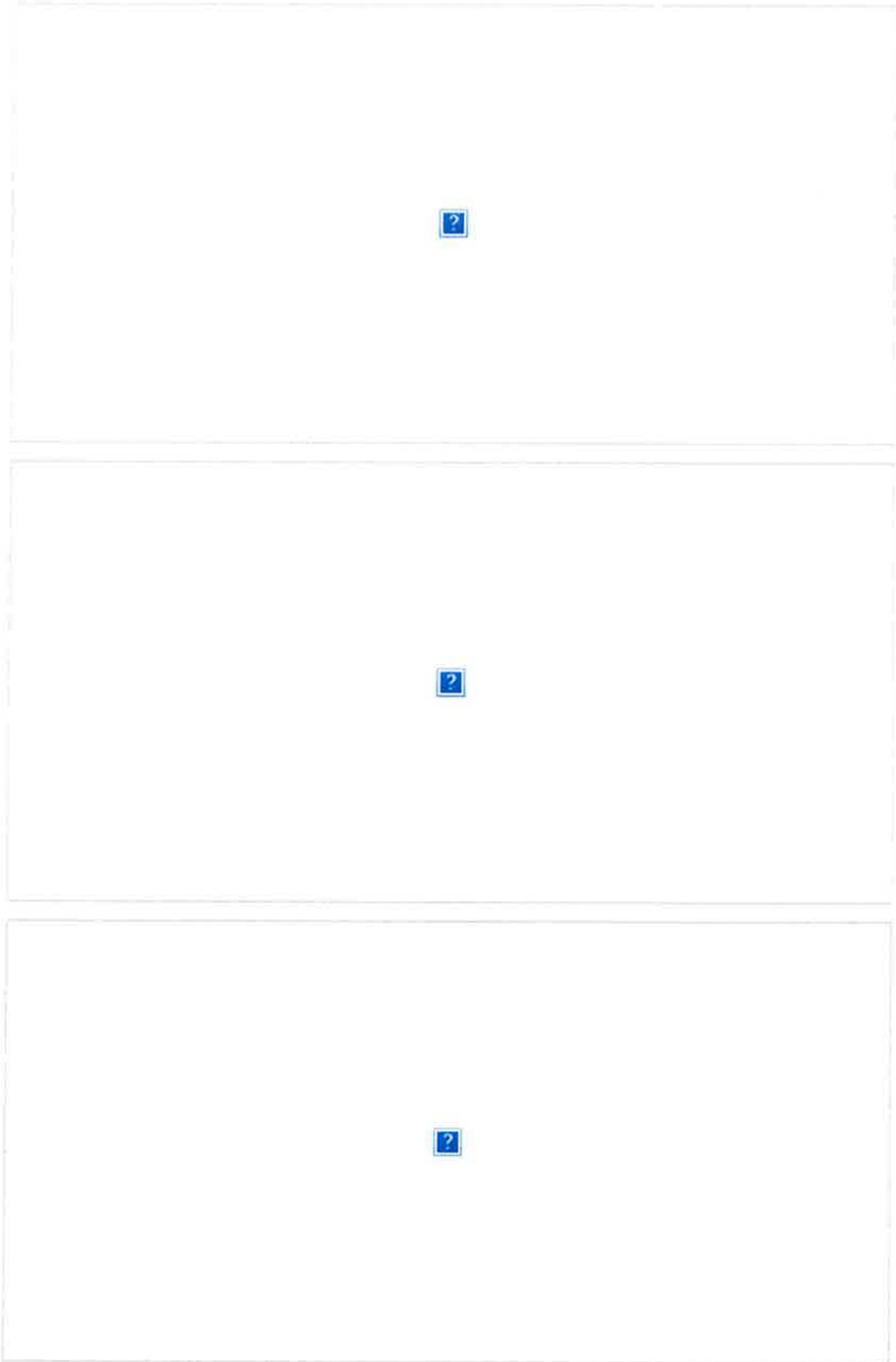


Figure 3. theta (top), S (middle), and σ_{θ} (bottom) along 75° 00'N. Uncorrected data.

[First page]

Salinity analysis of water samples

by F. Svendsen, F. Cleveland, and M. Bentsen

Instrumentation

The water saliniometer analysis were performed on a 8410 Portable Salinometer from Guidline, calibrated towards Oceanic Scientific Standard (IAPSO) Water (17 ampoules of P108, and 1 ampoul of P132). The accuracy of the instrument claimed by the manufacturer is 0.003 equvalent PSU. No temperature controlled laboratory exist on the ship. The laboratory used for for the salinometer analysis is in the middle of the ship and has no door directly out on deck. During analysis the room temperature was monitored. The room temperature varied from 18.1°C to 23.4°C, but most of the time it was held at 21-22°C. The bath temperature varied from 18.848° C to 19.875° C.

Data collected

At all stations, except at the 5 shallow stations, water was tapped from 5 or 6 depths, mainly from about 1000 m and deeper. At the shallow stations samples were only tapped at the deepest depth. The reason to not analyse at all 12 sample depths is mainly due to reduced analysis capacity, in addition to the fact that water samples in shallow water may be of questionable quality for calibration purposes due to large gradients. For each sample depth two samples were collected. One sample was analyzed during the course of the cruise with the instrumentation mentioned above about 24 hours after it was drawn, while one sample is brought ashore for analysis posterior of the cruise.

During the cruise 420 samples were analyzed. So far it is found that 15 samples are obviously erroneous. The analysis at St's 52--54 contains an apparently constant bias of 0.055 due to a failure in the adjustment of the instrument. These samples are however included into the dataset after adding the bias (equal to 0.055). For st.'s 71--79 there is an increase of about 0.002 compared to previous stations, which is not understood yet. Comparison with the CTD sensors is shown in Figure 5, Figure 6, and in Table 7.

In the property--property plots showed later on, as well in the distributed 'masterfile' from the cruise, is the salinity measured by the secondary minus the mean deviation (0.00122) found between the salinometer analysis and the electronic measured salinity (Table 7).

Table 7.

No of observations, mean, and standard deviation for the difference between the primary sensor and salinometer salinities (S_1-S_{bot}), secondary sensor and salinometer salinities (S_2-S_{bot}), primary and secondary sensor salinities (S_1-S_2), and primary and secondary temperatures (T_1-T_2).

	S_1-S_{bot}	**S_2-S_{bot}**	**S_1-S_2**	**T_1-T_2**
All Samples				
Observations	380	397	860	860
Mean deviation	0.00195	0.00122	0.00053	-0.00038
St. deviation	0.00178	0.00129	0.00090	0.00327
Samples below 1000 dbar only.				
Observations	278	289	364	364
Mean deviation	0.00223	0.00138	0.00075	-0.00027

St. deviation	0.00169	0.00124	0.00080	0.00080

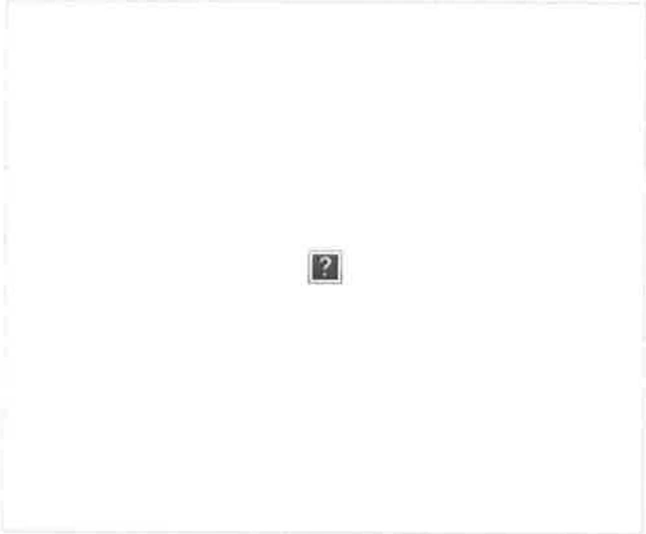
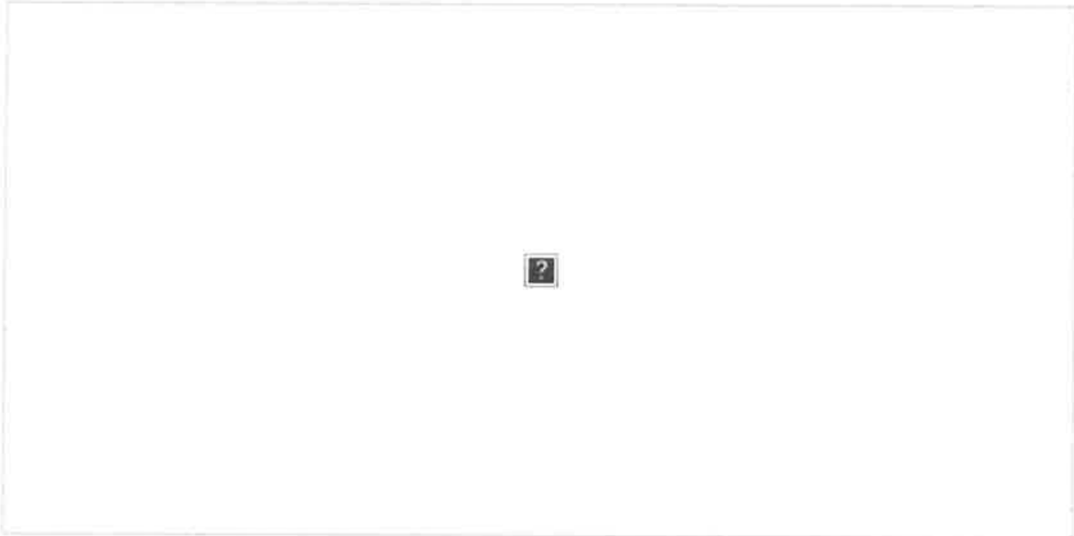


Figure 4. theta--diagram. The color contouring shows the pressure. The salinity is as measured by the secondary sensor minus 0.00122. }



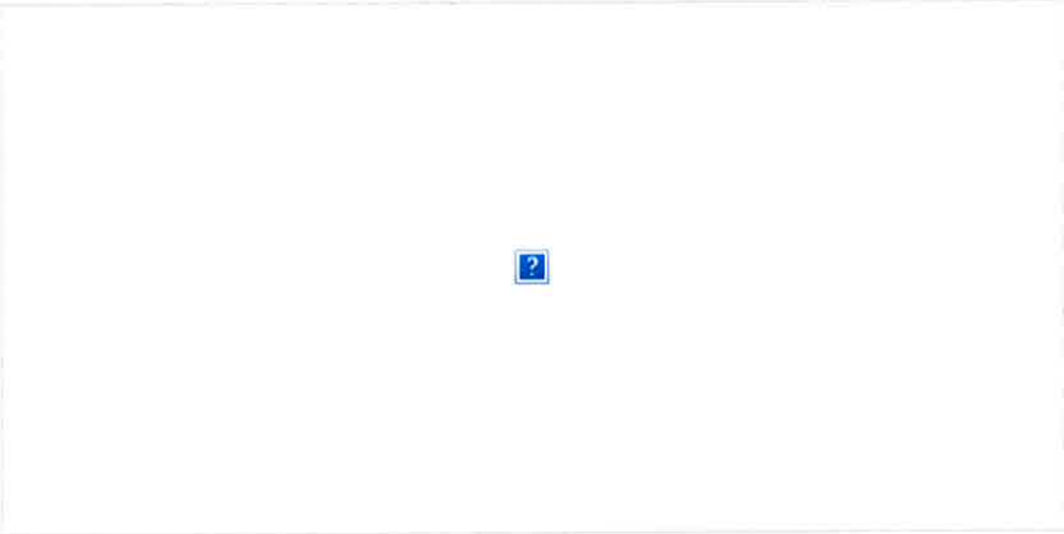
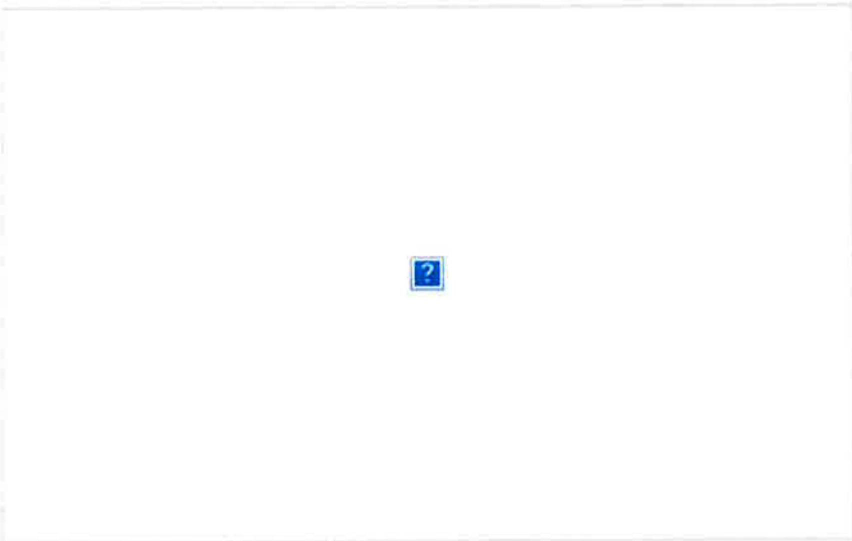
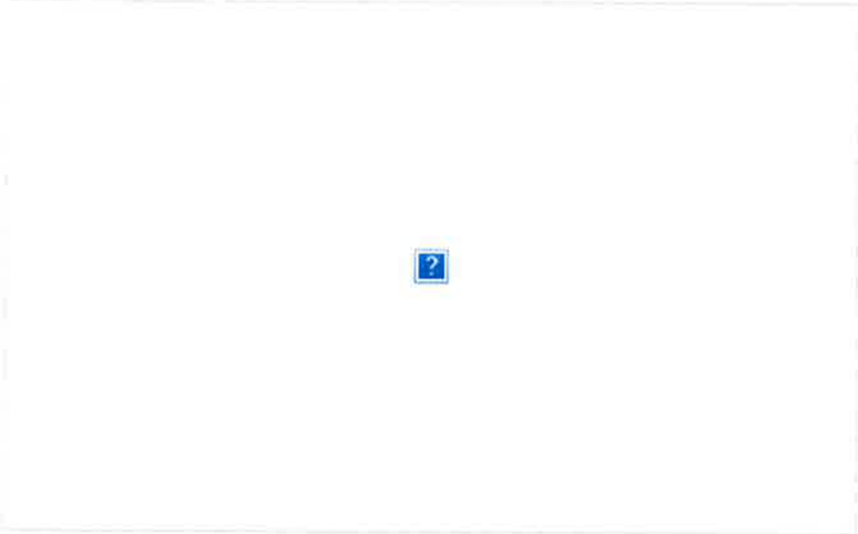


Figure 5. Deviation between primary sensor and saliniometer salinities (top), secondary sensor and saliniometer salinities (middle), and between primary and secondary sensor salinities at water sample depths (bottom) vs station number. Note that the primary sensor was replaced after station 23.





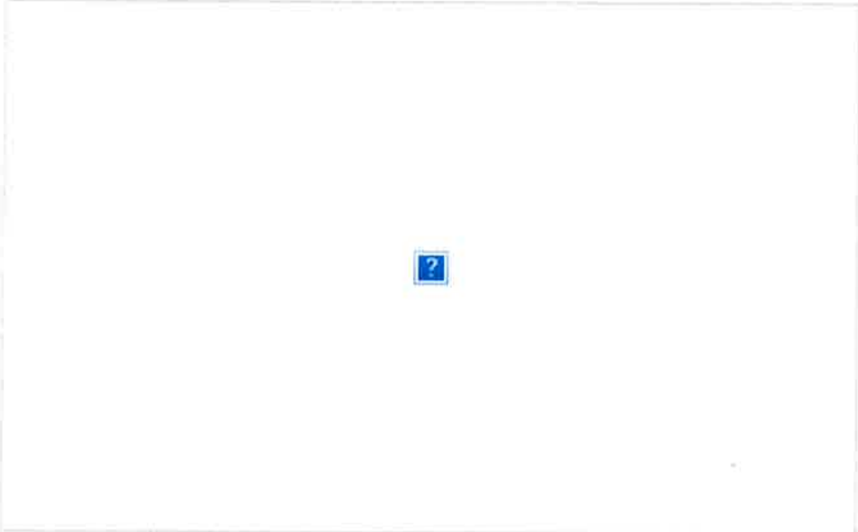


Figure 6. Deviation between primary sensor and saliniometer salinities (top), secondary sensor and saliniometer salinities (middle), and between primary and secondary sensor salinities at water sample depths (bottom) vs pressure. St. 14 deviate from the other stations due to too low values measured with the primary sensors.

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Oxygen analysis of water samples

by F. Svendsen, F. Cleveland, and C. N. Egset

Method

Bottle oxygen samples were taken in clear glass bottles immediately following the drawing of samples for SF6, and chemically fixed. Analysis followed the Winkler titration method.

Collected data

In total 493 samples are analyzed during the course of the cruise (see Figures 7 - 9). Further analysis and comparison with the CTD data has not been done yet.

Figure 7. SF6, Alkalinity, Oxygen, and TCO2 measured from water samples plotted vs pressure. Uncorrected data.

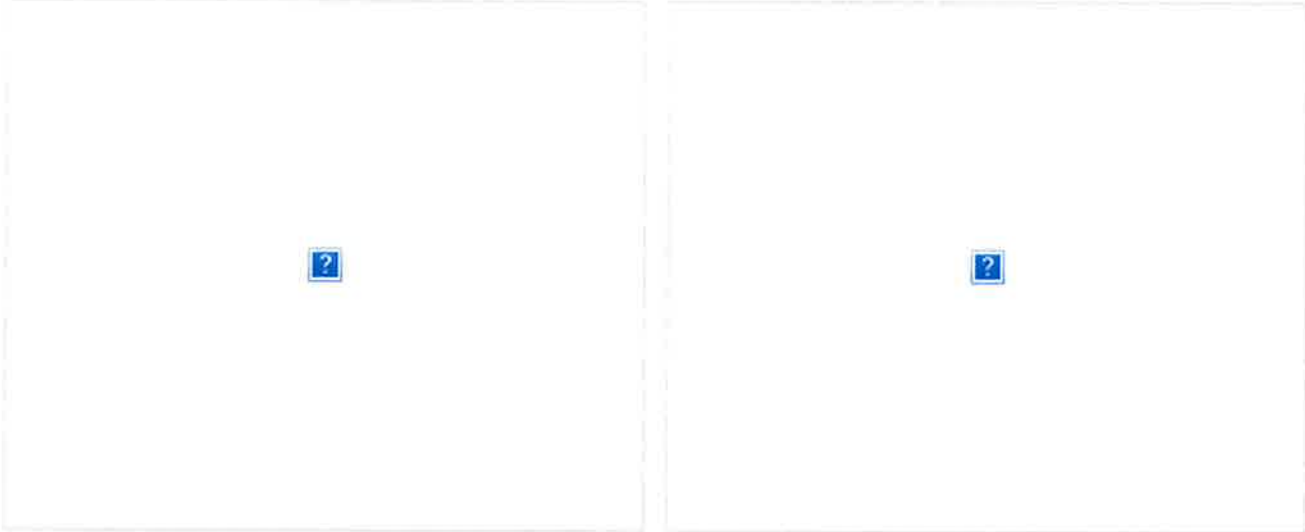

Figure 8. SF6, Alkalinity, Oxygen, and TCO2 measured from water samples plotted vs potential density. The color contouring shows the depth. In the SF6-plot are concentrations below 0.5 fmol/l not included. Uncorrected data.

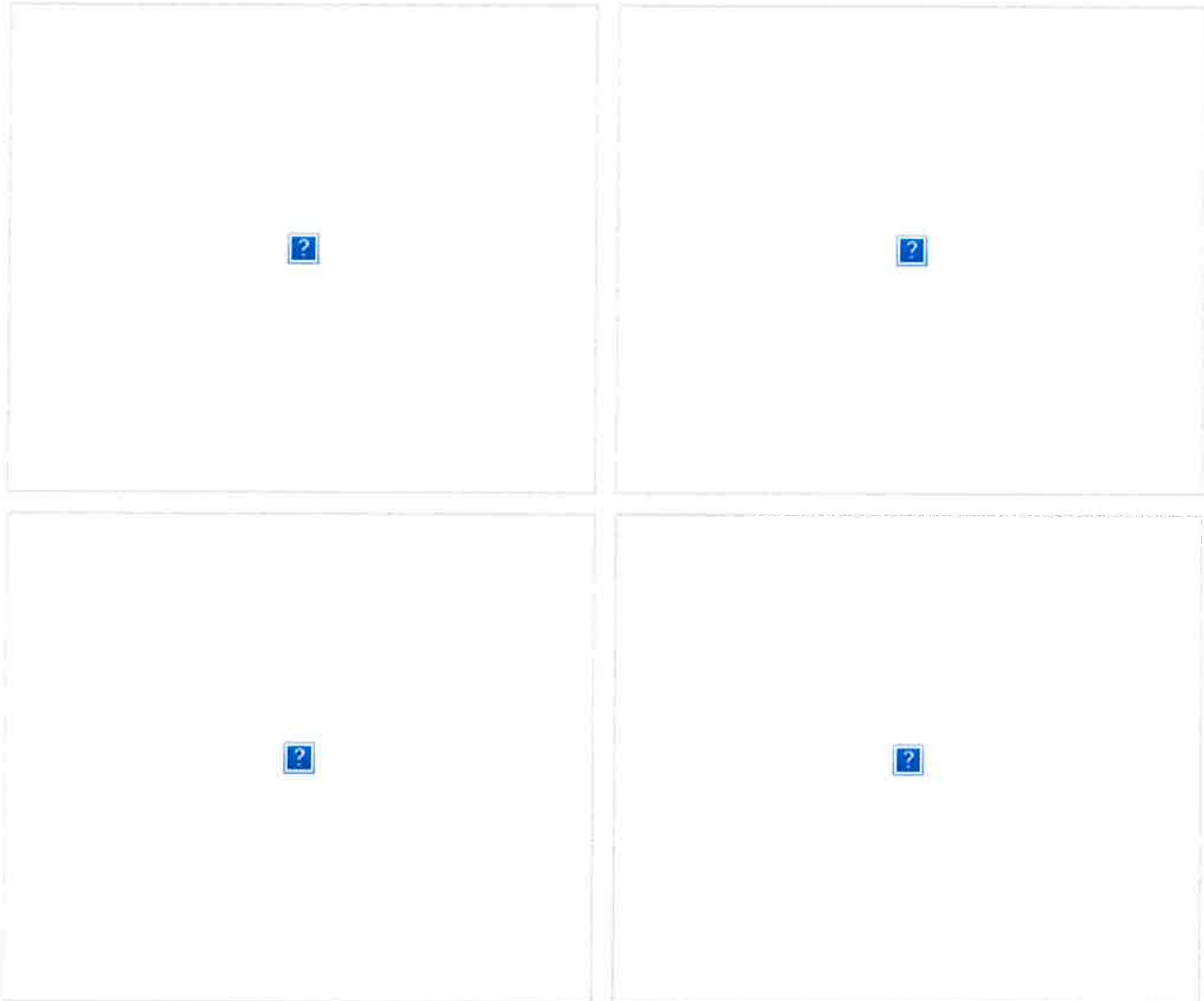

Figure 9. SF6, Alkalinity, Oxygen, and TCO2 measured from water samples plotted into a theta-S diagram. The color contours shows the concentrations. In The SF6-plot are concentrations up to 10 fmol/l

also indicated by the size of the scatters, but for concentrations above 10 fmol/l have the same scatter size. The units for TCO2 are mikro mol pr kg, and for alkalinity are mikro mol pr l. Uncorrected data.

[First page]

Sulphur Hexafluoride Measurements

by D. Cooper and J. Kruepke

Method and instrumentation

Sulphur hexafluoride (SF6) was measured using a purge and trap gas chromatographic system with electron capture detection. This system is essentially the same as used in two previous cruises during ESOP2 in 1997. The analytical system has a detection limit of approximately 0.1 femtomol/liter (fM) for 175 cm^3 samples, as used on the present cruise. Deviation between duplicate samples was calculated to be 0.7% for elevated SF6 concentrations and up to 0.1 fM for background samples. The larger uncertainty in background samples was due to baseline noise caused by the ships movement in heavy seas. Calibration was made using a gas standard previously referenced to Plymouth Marine Laboratory (PML, U.K.) via the University of East Anglia (UEA, U.K.) SF6 group during previous ESOP2 cruises. The preliminary cruise data will most likely be corrected slightly based on final confirmation of the SF6 standard from PML. Seawater samples were taken for SF6 analysis from all Niskin bottles on the CTD immediately the CTD was brought on deck. Standard volatile gas sampling procedures were followed, filling well rinsed 500 cm3 glass stoppered bottles to overflowing. The aims of the cruise were to:

- continue quantification of the horizontal and vertical spreading of the SF6 patch,

- study possible specific pathways for circulation and convection within the Greenland Sea gyre and

- study the unexpected development of elevated SF6 concentrations in central gyre bottom water, as tentatively reported from previous cruises.

Results

A total of 882 seawater samples were analyzed for SF6 from 78 CTD stations (Figures xx -xx). Concentrations above background level were found at all stations within the gyre, with maximums located near, but slightly shallower than the original target density of SF6 deployment (sigma_theta= 28.049). Weather, ice conditions and time constraints prevented a complete survey of the extent of the patch, however key locations, bottom concentrations and a thorough 75° 00'N transect were among several of the goals successfully accomplished. Preliminary results suggest bottom concentrations within the central gyre of 0.8--1.2 fM. Surface concentations varied from 2.5 to 5 fM with a few exceptions. The maximum SF6 concentration of 76.6 fM was found at 75° 00'N, 0.5° 00'W, with high values continuing north through 76° N latitude. The untimely onset of bad weather, prevented further investigation of the northern extent, however, samples analyzed from the September, 1997 Polarstern cruise confirm the spread of the tracer through 77° 55'N, 01° 01'E.

Overall, the survey of the gyre was satisfactory, with the exception of the area south and west of 74° N, 1° W . Due to the unpredictable nature of the ice conditions during this season, this area was not able to be safely reached. Several stations taken early in the cruise across the Jan Mayan Channel at approximately 71.3° N, 8° W, indicated above background levels of tracer were being transported through it. The tracer was present at all stations taken along the continental slope near Greenland, and also the eastern most stations at 75°N and 76° N, 7° E (Figure xx), though concentrations were diminishing at these points.

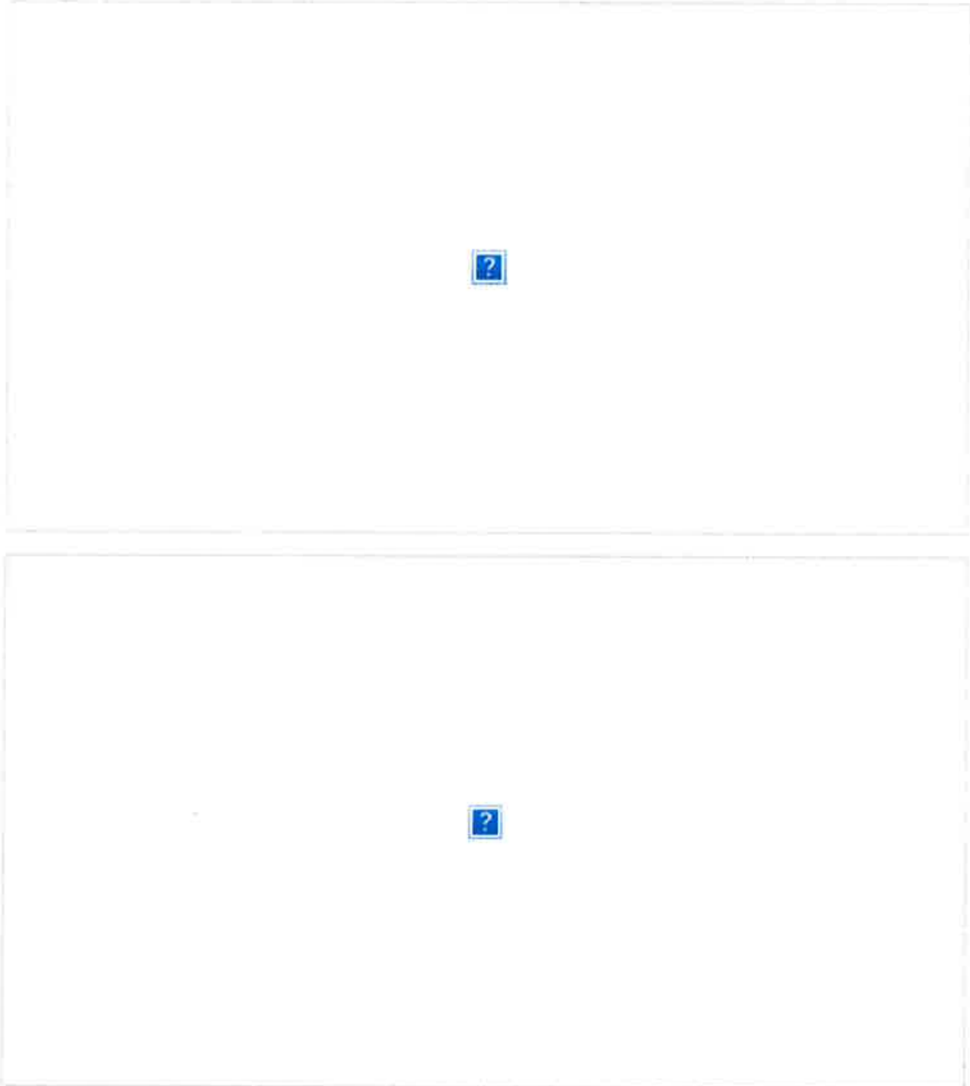

Figure 10. Contour plot of SF6 concentrations along 75° 00' N (upper) and along 76° 00'N (lower).

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Carbon measurements in IMCORP

by U. Schuster, A. Omar, and A. Olsen.

Introduction

In order to be able to increase the data sets collected for the marine carbon dioxide cycle, within the IMCORP project, automated instrumentation (called the VOS system) is being developed, which analyses surface seawater pCO2, TCO2, and pH, as well as marine air pCO2. It is designed to be a turn-key instrument which runs unattendedly whilst deployed on board ships, both scientific and merchant. This prototype has been developed by the University of East Anglia (UK) and was deployed on board R/V Håkon Mosby for its second sea trial in order to determine its performance in terms its analytical accuracy and precision under ship-board conditions, and in terms of its ability to run in an automated/unattended mode for long periods of time.

Discription of the instruments

The principal of detection of pCO2, and TCO2, is based on infrared absorption of gas-phase CO2, (by a LiCor 6262 CO2, and H2O detector), whilst the pH unit utilizes the acid-base properties of selected sulfonephtalein indicators trough the measurment of their absorption characteristics under different states of protonation.

Marine air was collected on the mast of the ship and pumped directly to the instrument. For the measurement of surface seawater parameters, an uncontaminated seawater supply was used. For seawater pCO2, the seawater was equilibrated with air in a packed bed seawater-air equilibrator, followed by the gas being passed throught the detector. For detailed discribtion of the pCO2, module see Cooper, 1996. For the TCO2 measurement, an aliquot of seawater was taken from a continuous bypass, acidified, and the released CO2, passed to the LiCor detector by CO2-free nitrogen carrier gas. The TCO2 was determined by integration of the CO2 concentration released from the seawater aliquot. For the pH measurement, the seawater was passed into a header tank, from which a continuous stream of seawater was mixed with a dye of specific concentrations, and the absorption measured at three wavelengths in a flowcell. See Bellerby, 1995, for details.

To calibrate the LiCor 6262 detector, standard gases of 200ppm and 400ppm CO2 in dry air were used. As standards for the TCO2 measurements, certified liquid standards were used (Andrew Dickson, Scripps Oceanographic Institute). A high frequency of standard analysis was performed on board ship for pCO2 and TCO2 measurements, in order to keep careful check on the performance of the instrument.

Achievements and problems encountered.

Prior to the cruise, a computer hardware problem had developed in the central electronic control unit of the VOS system, which was solved in time for the cruise, but the instrument could not be tested in the laboratory before installation on board. Therefore, at the beginning of the cruise, an unusually long time was needed to set up the instrument for relyable automated analysis. Once installation was completed, the system run continuously for 16 days. Minor problems with two solenoids in the TCO2 module were encountered and solved satisfactorily during the cruise.

Due to the deployment of the SOMMA, alkalinity and UoB underway pCO2 systems on board during the cruise (details under Carbon ESOP), an interlaboratory comparison of measured data was made possible for the first time. he frequent analysis of standards showed a LiCor detector drift over the time period of the cruise, beyond the drift observed in the UoB underway system. However, good agreement of pCO2 in marine air and surface seawater was obtained, when comparing the two different systems. The results of marine air pCO2 data collected with the two systems are shown in Figure 11, with the results of seawater pCO2 are shown in Figure 12

Figure 11. Uncorrected data of marine air pCO2 analysed by the VOS (a) and by the UoB (b) underway systems during the period of the cruise.

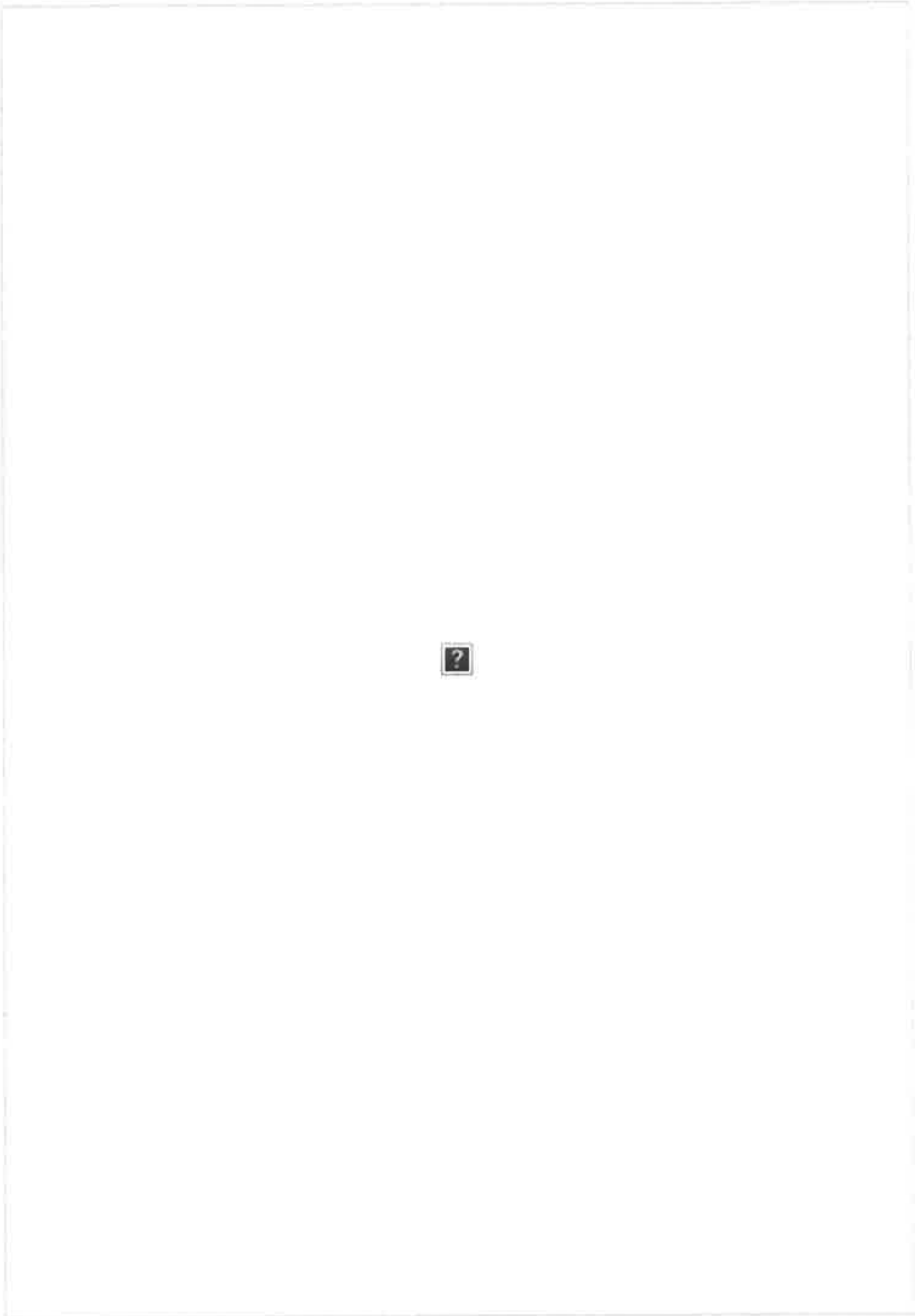

Figure 12. Uncorrected data of surface seawater PCO2 analysed by the VOS (a) and by the UoB (b) underway systems during the period of the cruise.

The TCO2 values measured by VOS system are recorded in the unit (5micro-mol/mol)/ml, while the TCO2 values measured by the SOMMA system are given in 5micro mol/kg. Therefore, to compare the surface seawater TCO2 results from the two systems, we had to know the temperatures at which the samples were analysed. Due to malfunctioning of the temperature probe of the VOS TCO2 module, this comparison could not be done. However, we are planning to do indirect comparison later by using the results from the Dickson standards that has been analysed by both systems at known temperatures.

Concerning the pH unit, a pre-cruise problem was finding the optimum concentration of the indicator solution and mode of injection. Therefore, during the cruise, it was decided to test different concentrations of indicator solution and modes of injection to find the optimum for use under ship-board conditions. The optimum indicator solution was four times more concentrated than previously used ones, which will make the system self-substainible for a longer period of time.

During the cruise, the pH readings obtained were lower than expected, which could either be caused by the fact that the indicator was disolved in deionised water (pH approximately 5.5), or by the increased temperature of the seawater analysed after it had passed through the header tank and pH system (insufficient insulation of the thermistor upstream of the flow cell). New indicator solution was tested, which was prepared using surface seawater off the uncontaminated seawater supply. This did not increase the pH readings significantly and the first option was discarded. Further tests concerning the temperature measurement in the system and more detailed data analysis will be performed back in the laboratory in Bergen.

[First page]

Carbon cycle measurements in ESOP2

by A. Olsen, J. Delaney, C. N. Egset, F. Cleveland, and F. Svendsen.

Background and Objectives

For the ESOP II project, the changes in the carbon dioxide system throughout the whole water column of the Greenland Sea gyre are of interest. Therefore, samples from CTD profiles were taken for the analysis of dissolved oxygen, TCO2, alkalinity, d13C, d18O and nutrients. Instruments deployed on board by the University of Bergen for immediate analysis of seawater samples were: the SOMMA system for TCO2 samples and alkalinity instruments for alkalinity. Dissolved oxygen was determined by the Winkler method. Samples for d13C, d18O and nutrients were stored for later analysis in the laboratory in Bergen. Additionally, the UoB pCO2 underway system was deployed for the continuous analysis of surface seawater and marine air pCO2.

Description of the SOMMA system

Seawater samples from the CTD were analysed for TCO2, using a SOMMA system (Single-Operator Multiparameter Metabolic Analyzer System) with coulometric detection (UIC, model 5012), developed by K.M. Johnson, Brookhaven National Laboratory, N.Y. The SOMMA operates by dispensing and acidifying a known volume of seawater, stripping the released CO2, from the solution by nitrogen carrier gas, drying the gas, and then measuring the amount of CO2, coulometrically in the detector. When the coulometric cell became exhausted or unstable, a fresh cell was made up. A new cell was put through a series of calibrations, including non-specific seawater, CO2 gas standards s(HydroGas, Norway) and liquid standards (Andrew Dickson, Scripps Oceanographic Institute). Periodically during the analysis procedure a replicate measurement would be made using a seawater sample and or a Dickson standard to check for consistency in the results. This was done in particular on samples where it was suspected that the coulometer cell may be exhausted.

During the cruise a total of 78 stations were visited and 698 samples analysed, the uncorrected data of which are listed in Table 2 in the Appendix. One frequently occurring problem during the cruise was inaccuracy of results due to an unstable coulometer cell, (not always an exhausted cell). The replacement cell and the subsequent calibration procedures are a lengthy process and on occassion incured a backlog of samples. In this situation the samples were poisoned with saturated HgCl2 in order to provide a means of preservation.

The alkalinity instrument

The seawater alkalinity is defined as the number of moles of acid that must be added to neutralise all the strong bases in the sample with pKa higher than 4.5. In practice, the alkalinity of a seawater sample was determined by bringing the sample to room temperature and titrating an aliquot of seawater with HCl (0.04946 M) and following the potential of the solution with an Ag/AgCl sure-flow electrode (Orion Research), until the alkalinity titration curve was completed (pH approximately 3).

Results

During the cruise a total of 78 stations were visited and 743 samples analysed for alkalinity. The uncorrected data are listed in Table 2 in the Appendix. Periodically, replicate measurements were made on seawater samples and/or Dickson standards (with certified alkalinity) to check for repeatability of the titration and stability of the elctrode. On two occassions problems were encountered involving the electrode. The first problem developed when the electrode started to give unstable results, and it proved impossible to re-calibrate it. Therefore the electrode was replaced. The replacement electrode worked satisfactorily until station 77, where it ceased to operate possibly due to scratching on the surface. Therefore we were unable to analyse samples from stations 77, 78 and 79.

The UoB underway CO2 system

This system works on the same principle as the part of the IMCORP instrument which analysis surface seawater and marine air pCO2. It is in fact a previous version of the system used for IMCORP, and has been extensively used at sea. It is therefore a proven instrument in terms of its analytical accuracy and precision. Additionally to its use for collection of ESOP II data, during this cruise it was used for an interlaboratory comparison with the prototype under IMCORP. It was mapped a drift in the alkalinity results during the cruise, this will be corrected for as soon as possible. The comparison of marine air and seawater pCO2 with the VOS system's results are shown in Figure 11 and Figure 12 respectively.

[First page]

Underway measurements of sea surface salinity and temperature

by K. Simonsen

Instrumentation

Sea surface temperature is measured at 2 m depth by an Aanderaa weather station. In addition attempts were made to measure underway temperature and salinity with a Multipar mini CTD placed in a tank on the deck. Water was pumped from about 2 meter depth into the tank. These data were logged and monitored on a PC dedicated to this purpose. However, due to heating when the water is transported through the pipe system from the sea water inlet to the tank, the temperature is unreliable, although relative changes in the temperature may be seen. Since the temperature is unreliable, and the measured conductivity is closely related to the temperature, accurate absolute salinity data was not expected either. However, by post cruise calibration towards the surface values from the main CTD, and surface water sample salinity the aim is to obtain mapping of the relative changes in the salinity along the ship track.

Data collected.

The measurement of sea surface temperature started immediate after departure from Bergen, and stopped again at the same position at the end of the cruise. The mini--CTD arrangement was started when we entered the Greenland Sea the 9'th of March and switched of again on the way out of the Greenland Sea on 23'th of March.

[First page]

Current profiles

by K. Simonsen

Instrumentation

The vessel is equipped with a 150 kHz Acoustic Doppler Current Profiler (ADCP) from RD Instruments. The ADCP is connected to a PC, which handles the data logging both from the ADCP and navigation data. The sound velocity was set constant equal to 1500 m/s and the salinity equal to 35.0 ppt. Unfortunately, one of the four transmitter in the ADCP had reduced signal intensity, and was consequently switched off. The current may still be estimated from the three remaining beams, but it is not possible to come up with an error estimate. Repair of the transmitter require that ship must on dock, and this was not possible to do prior to the cruise. The navigation data is provided by an newly installed Seapath from Seatex. The Seapath receives continuously GPS positions from as many satellites as possible and estimates the ships position, velocity and direction.

Observations

Prior to the cruise the new Seapath system was only checked together with the ADCP in bottom tracking mode, which is not usable at depths larger than say about 400m. When switching the ADCP to navigational mode it failed. The 16'th of March the problem was solved, and the performance of the ADCP was excellent until it was switched off the 24'th of March. It may be noted, that during periods of bad weather the ADCP data becomes questionable. No processing or analysis of the data was done during the course of the cruise.

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[First page]

Measurements of meteorological variables

by K. Simonsen

Instrumentation

R/V Håkon Mosby is equipped with an Aanderaa automatic weather station. The measured variables are wind direction and wind speed, air temperature, relative humidity, and sea temperature at 2 m depth. Absolute wind speed and direction is obtained by correction of the ships movement measured by a Simrad NL speed log and by the Gyro compass (SGB 1000). The anemometer and thermometer is placed in the ship's mast about 17 m above sea level. All measurements are 10 minutes averages. New anemometer was mounted Nov. 5., 1996, the relative humidity unit was changed the June 26., 1996, and the under water thermometer was controlled Oct. 11., 1996. Generally the meteorological station is controlled at least once a year by the manufacturer, but the only documentation found onboard the vessel concerning calibration of the instruments measuring air temperature and pressure are from February, 1993.

Observations

The weather station worked excellent during the entire cruise. The first registration was made when we left the harbor in Bergen, and the last registration was made at the end of the cruise few hours before the ship docked in Bergen.

The wind measurements logged by the weather station is corrected for the ship movement obtained from the Simrad NL speed log and direction from the Gyro compass in order to provide true wind speed and direction. These corrections are done continuously by the system onboard the ship. During the cruise it was noted that the Simrad NL speed log in general under estimated the speed compared to the speed obtained from the GPS. Based on data from previous cruises, it is shown that the deviation in the ship speed estimated by speed log and from the GPS positions may be up to 2 knots. Modifications of the system to use data from the Seapath is planned.

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Ice observations

The ice conditions was very favorable for a non-icegoing vessel, as previously mentioned, and those are the observations of ice quite few. During the cruise Danish Center for Remote Sensing (DCRS) and Danish Metological Institute (DMI) produced icemaps for the area and send them directly to the ship via the Imarsat sattlite telephone system. On the surface the ice conditions were documented through a camera whenever ice was observed in daylight.

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Ackowledgement

Sincerely thanks to master Ole M. Røttingen and his crew for splendid cooperation and for their guidance and help in both small and big matters during the cruise. Thanks to Danish Center for Remote Sensing and Danish Metological Institute for providing us with icemaps. This work is supported by the MAST Programme of the European Union through the ESOP-2 project under contract No. MAS3-CT95-0015 and through the IMCORP project under contract No. MAS3-CT95-0023. The deployment of the current meter mooring is part of the Regional Climate project financed by the Norwegian Research Council.

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Appendix

Table A1: Station summary table

Table A2: Masterfile containing water sample data. (Separate table enclosed)

The winter cruise 1998 as seen through the camera.

[First page]