“22.10.2002 Polarstern 24.4.-14.5.2003 Jnr. 2002/18519”

Cruise Report of the Expedition ARKTIS XIX/2 of the Research Vessel “Polarstern“

Edited by Gerhard Kattner with contributions of the participants

Coordinator Eberhard Fahrbach

Chief Scientist Gerhard Kattner

INHALT / CONTENT

2 Fahrtabschnitt / Cruise leg ARK XIX/2

LONGYEARBYEN - BREMERHAVEN

April 24 to May 14, 2003

2.1 Zusammenfassung und Fahrtverlauf

G. Kattner (AWI)

Der 2. Fahrtabschnitt der 19. Polarstern-Expedition in die Arktis startete am 24. April 2003 in Longyearbyen auf Spitzbergen. Von dort ging es zunächst in Richtung Bäreninsel, wo die ozeanographischen Untersuchungen mit einem Schnitt entlang 75°N begonnen wurden, der bis zum grönländischen Schelfgebiet führte (Fig. 2.1.1). Dieser Schnitt wird jährlich wiederholt, um Veränderungen der Wassermassen insbesondere der Tiefen- und Bodenwassermassen der Grönlandsee langfristig untersuchen zu können. In diesem Jahr konnte aufgrund der frühen Jahreszeit die großräumige hydrographische Struktur unmittelbar nach den Konvektionsereignissen im Winter erfasst werden. Die sehr komplexen Vorgänge sollen zum einen durch die Untersuchungen während der 75° Schnittfahrten und zum anderen durch autonome Jojo-Verankerungen geklärt werden. Die Verankerungen ermöglichen die detaillierte Aufzeichnung der Prozesse während des ganzen Jahres. Das herausragende Ergebnis der diesjährigen Untersuchungen war das Auffinden und Vermessen eines konvektiven Wirbels, der die größte Konvektionstiefe hatte, die in den letzten Jahren gefunden wurde. Das Temperaturmaximum, das normalerweise bei etwa 1700 m liegt, lag hier in einer Tiefe von 2700 m.

Neben den hydrographischen Untersuchungen wurden während des 75° Schnitts sowie auf dem grönländischen Schelf und am Hang die Nährsalzkonzentrationen gemessen, um im Vergleich zu früheren Fahrten die saisonalen und jährlichen Veränderungen bestimmen zu können. Nitrat und Phosphat, deren Verhältnis sowie Silicat haben sich als gute Tracer für den Ausstrom arktischen Oberflächenwassers, das zum Teil auch pazifischen Ursprung hat, erwiesen. Während dieser Expedition wurden jedoch keine Anteile pazifischen Wassers gefunden. Ein weiterer Schwerpunkt war die Erfassung von Fluoreszenzprofilen im Ostgrönlandstrom und die Korrelation der Fluoreszenzsignale mit den hydrographischen und chemischen Daten. Mit diesen Untersuchungen werden wir eine bessere Abschätzung des Volumentransports an terrigenem Material im Ostgrönlandstrom erzielen können.

Die optischen Eigenschaften des Meerwassers wurden bestimmt, um eine direkte Validierung von Fernerkundungsdaten vorzunehmen. Dazu gehörten die Messung der Strahlungsdichte über dem Wasser und der Konzentration von Stoffen, die optisch aktiv sind sowie die Bestimmung der optischen Eigenschaften. Ziel der Untersuchungen war es, das Verständnis der Variabilität von optischen Eigenschaften zu verbessern und Daten für der Entwicklung und Verbesserung von Fernerkundungsalgorithmen zu sammeln.

Ziel der biologischen Arbeiten war die Untersuchung der Vertikalverteilung des Zooplanktons in der Grönlandsee in Fortsetzung der Arbeiten auf dem vorherigen Fahrtabschnitt. Da die älteren Stadien den Winter in tiefem Wasser verbringen, sollen die Daten aus dem Frühjahr Aufschlüsse über den Zeitpunkt des Aufstiegs in die euphotische Zone und über die Gonadenreife ergeben, um bessere Informationen über den zeitlichen Verlauf der Reproduktionsbiologie zu erhalten.

Nach Beendigung der Arbeiten auf dem grönländischen Schelf brauchte Polarstern dann noch 5 Tage, um am 14. Mai 2003 wieder in Bremerhaven einzulaufen.

Itinerary and summary

The second leg of the Polarstern expedition ARK XIX to the Arctic started in Longyearbyen on Spitsbergen on the 24th of April 2003. We steamed towards Bear Island to the eastern end of the transect along 75°N across the Greenland Sea (Fig. 2.1.1). The hydrographic observations are repeated for many years to investigate the variability and changes of the Greenland Sea water masses with respect to deep and bottom water formation. During the expedition the large scale hydrographic structure was assessed immediately after the winter cooling period. The complex conditions were studied by oceanographic measurements during the Greenland Sea transect and by autonomous Jojo-moorings. These moorings allow detailed records of a complete yearly cycle. The most outstanding single feature of the survey in the Greenland Sea was the convective eddy. This feature represents the deepest convection level observed in recent years. The ubiquitous temperature maximum (found usually at medium depth levels of about 1700 m) was displaced downwards to 2700 m.

Along the 75°N transect and on the Greenland shelf nutrient concentrations were determined to monitor interannual and spatial variability. Nitrate and phosphate and its ratio as well as silicate are good tracers for the outflow of upper halocline Arctic surface water flowing along the Greenland continental slope. Part of this water mass is probably of Pacific origin but during this expedition no signature of water masses from the Pacific could be detected. Another topic was the determination of fluorescence profiles in the East Greenland Current (EGC) and their correlation with hydrographic and chemical data. These studies will allow a better estimate on the amount of terrigenous carbon transported from the Arctic Ocean via the EGC to the North Atlantic.

The optical properties of seawater were determined for direct validation of optical remotely-sensed data. The radiance above the water was measured, which mimic the satellite-borne sensors. Concentrations of optically active constituents in the water and optical properties of these constituents were determined. The primary objective was to acquire data for improving our understanding of the ocean optical properties and for developing/refining ocean colour algorithms for the investigated polar waters.

Biological work focused on the seasonal ontogenetic migrations of zooplankton continuing work started on the previous cruise leg. This time series will allow to determine the timing of developmental ascent after overwintering and gonad maturation and will reveal better information of the reproduction biology of zooplankton species.

After finishing our research in the East Greenland shelf area Polarstern needed 5 days back to Bremerhaven, where she arrived on the 14th of May 2003.

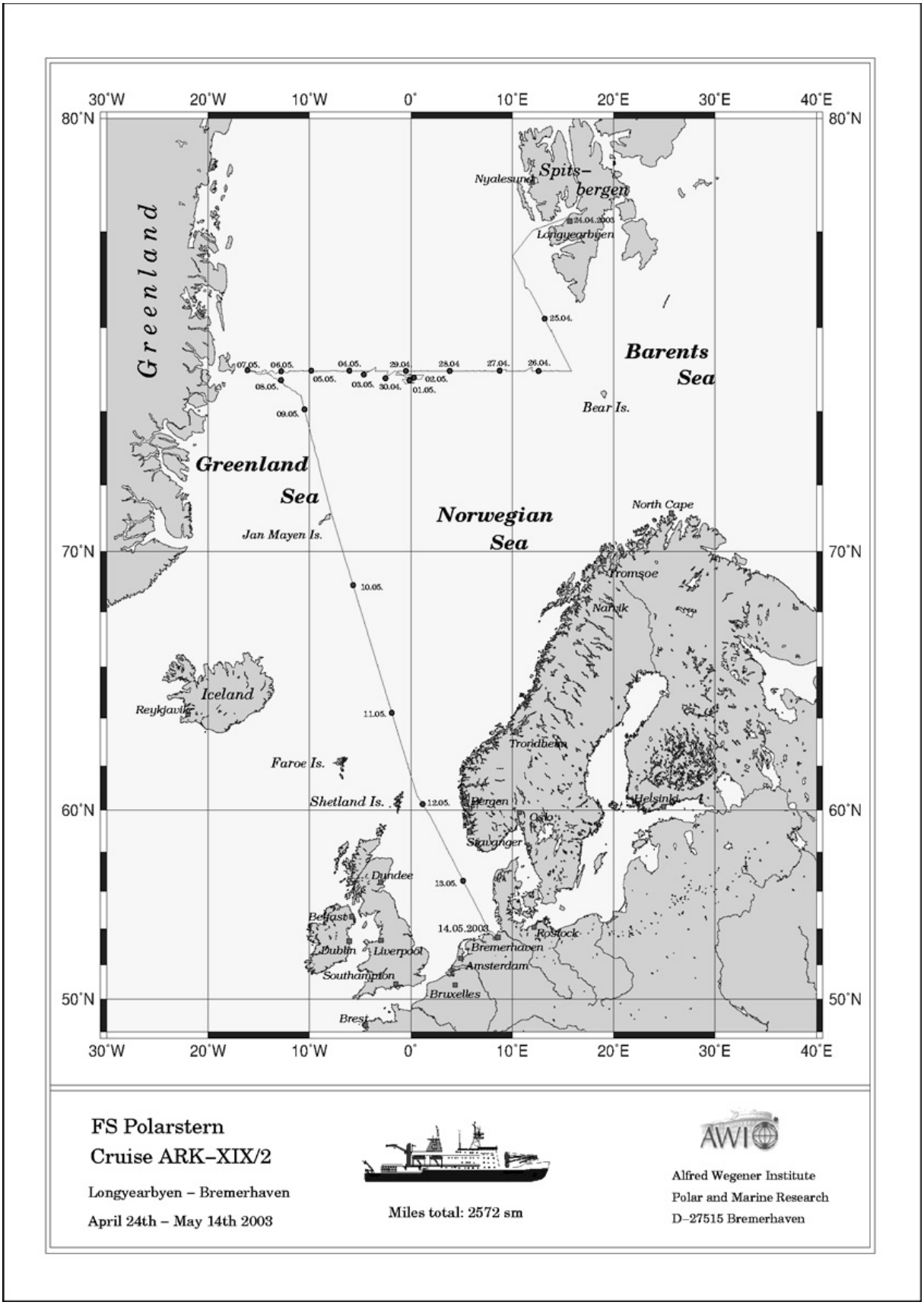

Fig. 2.1.1 Cruise track of RV Polarstern during the ARK XIX/2 expedition

2.2 Weather conditions

E. Knuth (DWD)

On April 24 at about 18:00 local time RV Polarstern left the Isfjorden on Spitsbergen under sunny conditions and temperatures of minus 10°C heading for Bear Island. The transit to the 75°N transect north of Bear Island was influenced by a high pressure system over Greenland. On the evening of April 25 the investigations began along 75°N, going west. Moderate to fresh easterly winds and a sea of about 2 m occurred. The following work was dominated by a stable northerly flow, accompanied by some heavy snow showers. The temperatures encountered were between minus 10 and minus 3°C. For a short time the investigations were influenced by small polar lows, which developed southwest of Spitsbergen and caused winds of 7 to 8 Bft and a sea of 4 to 4.5 m. The synoptic situation was dominated by a high with northerly winds of 4 to 5 Bft and a sea of 2-3 m over north and central Greenland.

During the night from May 2 to 3 RV Polarstern encountered the first light sea-ice of this leg. From May 5 light to moderate south easterly winds predominated and did not hinder the station work within the ice. In the afternoon of May 7 the most westerly station was reached near 75°N 16.3°W. The weather was sunny and only light southerly winds occurred. At noon of May 9 the last investigations were completed under south easterly winds of Bft 2 and temperatures of minus 4°C.

The cruise back to Bremerhaven began with light to moderate winds. The ice coverage decreased and the last ice was observed during the following night. Late on May 9 a light to moderate wind came from westerly directions and veered northerly in the following night. Then RV Polarstern came near to the northern flank of a low pressure system southwest of Iceland, which moved slowly east. This weather condition caused northerly to north easterly winds of Bft 4 to 6. From May 11 until the end of the cruise a trough over the Hebrides and Irish Sea moved slowly east. Under its influence the wind turned to southerly, later south westerly directions. The wind force was moderate to strong, accompanied by local showers. RV Polarstern arrived in Bremerhaven at noon of May 14. Frequency of wind speeds and directions are given in Figs 2.2.1 and 2.2.2.

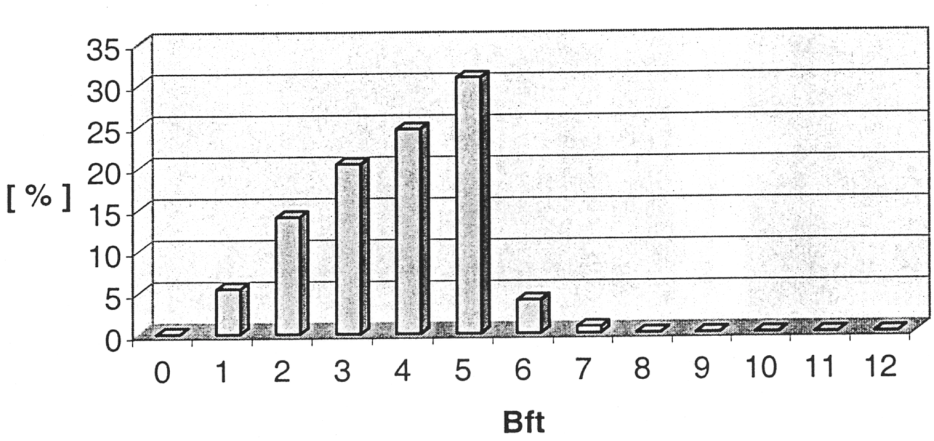

Fig. 2.2.1 Frequency of wind speeds during ARK XIX/2

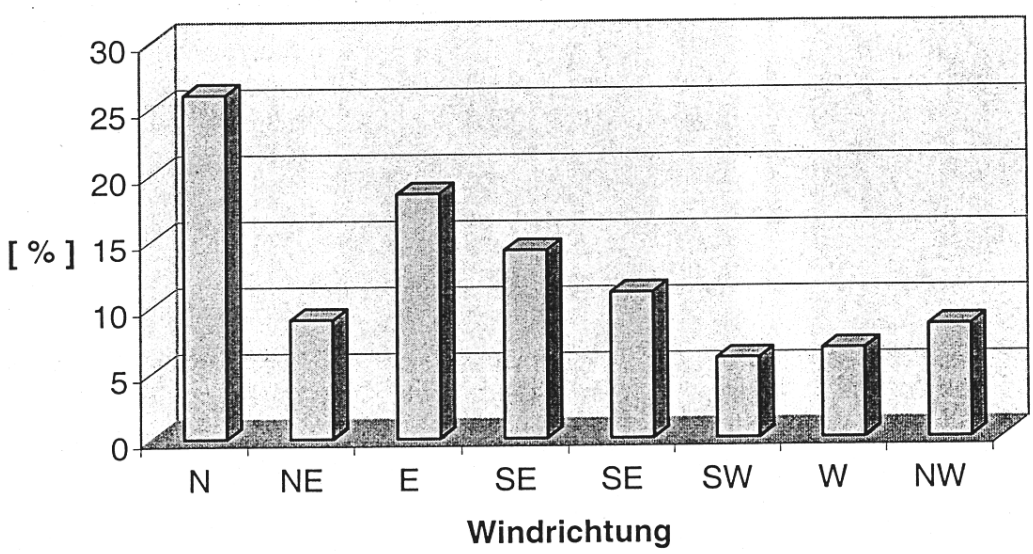

Fig. 2.2.2 Frequency of wind directions during ARK XIX/2

2.3 Hydrographic conditions in the Greenland Sea

G. Budéus, S. Ronski, R. Plugge, J. Schwarz, L. Gerull, J. Otto,
S. Breitenbach (AWI)

Bottom water renewal in the Greenland Sea by deep convection in interplay with ice coverage and atmospheric forcing is a major element of the water mass modification in the Arctic Mediterranean. Effects influence both the central Arctic Ocean and the overflow waters into the Atlantic. Since the hydrographic observations became more frequent in the late 1980s, no bottom water renewal by winter convection took place. However, under these conditions, the deep water properties changed towards higher temperatures and salinities. Furthermore, the doming structure in the Greenland Gyre, as it was observed in the mid-80s, was superseded by an essentially 2-layered water mass arrangement with a marked density step which is located presently at about 1700 m. The specific objectives of the project, which is incorporated in the EU funded 'CONVECTION', are to investigate the relative importance of atmospheric forcing parameters for winter convection, to clarify whether ice coverage inhibits or facilitates deep convection, to build a long term observational basis about deep water changes in the Greenland Gyre, and to contribute to the decision which deep water exchange mechanisms are at work under the absence of deep winter convection. A special focus is put on a long-lived submesoscale coherent vortex (SCV). Within this eddy, winter convection penetrates usually to considerably greater depths (about 2600 m) than in the surrounding waters. The eddy has a diameter of only 20 km, and as it shows no surface signal it is difficult to detect.

Work at sea

In the central Greenland Sea, a long term zonal CTD transect at 75°N has been performed with a regular station spacing of 10 nautical miles. This distance has not

been reduced at frontal zones in order to gain time for a couple of stations dedicated to the search and investigation of the SCV. CTD and water sampler (SBE 911+ with duplicate sensors, SBE Carousell 24 bottles of 12 L each) worked faultlessly. Additional sensors were attached for oxygen concentrations, chlorophyll fluorescence, and Gelbstoff fluorescence.

It is not possible to describe the full details of calibration and data procedures here. A few hints may suffice to give an idea about the general procedure. We use the same sensors already for a number of years and checked for their performance with respect to unwanted cross dependencies. According to this, one of the temperature sensors shows a pressure sensitivity of roughly 1.5 mK/4000 dbar while no pressure or temperature dependence of the conductivity sensors could be found. To identify the latter is close to impossible in the field (within the polar oceans) because of the high gradients in the upper water column where temperature differences occur. The locations of in-situ comparisons have been chosen carefully by checking for each data point whether a comparison is allowed or inhibited. Time alignment has been optimised for each flow path separately (reference station 138) and will be applied together with final post cruise calibration. The difference between pre-cruise and post-cruise calibration is normally in the range of a few mK and a few 1/1000 in salinity. Bottle sample salinities of quadruple samples are determined as a rough check on board, in the lab on land, and by Ocean Scientific.

We started to search for the convective eddy (SCV) at April 27th. A triangle grid formed by equidistant station points was constructed, where the distance between each station pair was 7 nautical miles. This seemed to be the largest allowed distance when looking for a feature of 20 km diameter. As instruments we used deep cast XBTs which have a nominal range of 1850 m (T5, Sippican). Frequently they provided data to 2000 m. Ship speed has to be reduced to about 7 knots when throwing them. Since the cast duration is only about 5 minutes, this does not seriously effect the ship's progress. Software has been used which was specially modified for the actual task of our eddy search. It contains an optional one degree Celsius temperature range with a free choice of the lower temperature scale value. So the vertical structure with the surface warm layer (or its lack) and the mid depth temperature maximum (and its depth) could easily be recognized. Starting at 20:00 in the evening, we were so lucky to detect the eddy already during the next morning at about 5 o'clock and threw XBTs with the double frequency then in order to localize the eddy as well as possible with this rough tool.

The position of the eddy core was 74°50.5 ‘N, 00°03.5’W on 29 April 2003, and we performed a south-north and an east-west transect (of 8 stations each) across its centre. Transect plots of preliminarily calibrated data are shown in Fig. 2.3.1.

Three in house developed EP/CC (externally powered/compressibility compensated) Jojo-moorings have been exchanged during the worst weather conditions encountered within this cruise. Nevertheless, work went smoothly and no loss of instruments occurred.

First results

The most outstanding single feature of the survey in the Greenland Sea was certainly the convective eddy. This feature represents the deepest convection level observed in recent years. It was found close to the 0° meridian a few miles south of 75°N with

the ubiquitous temperature maximum (found usually at medium depth levels of some 1700 m) displaced downwards to 2700 m. The eddy contains water which is denser than the surrounding at low pressure levels (about 600 m), but considerably less dense at higher pressures. This indicates that the water within the eddy is not a good candidate for bottom water replacement. Its lifetime by now exceeds two years. As is true for the background of the Greenland Gyre interior, the eddy is not well ventilated

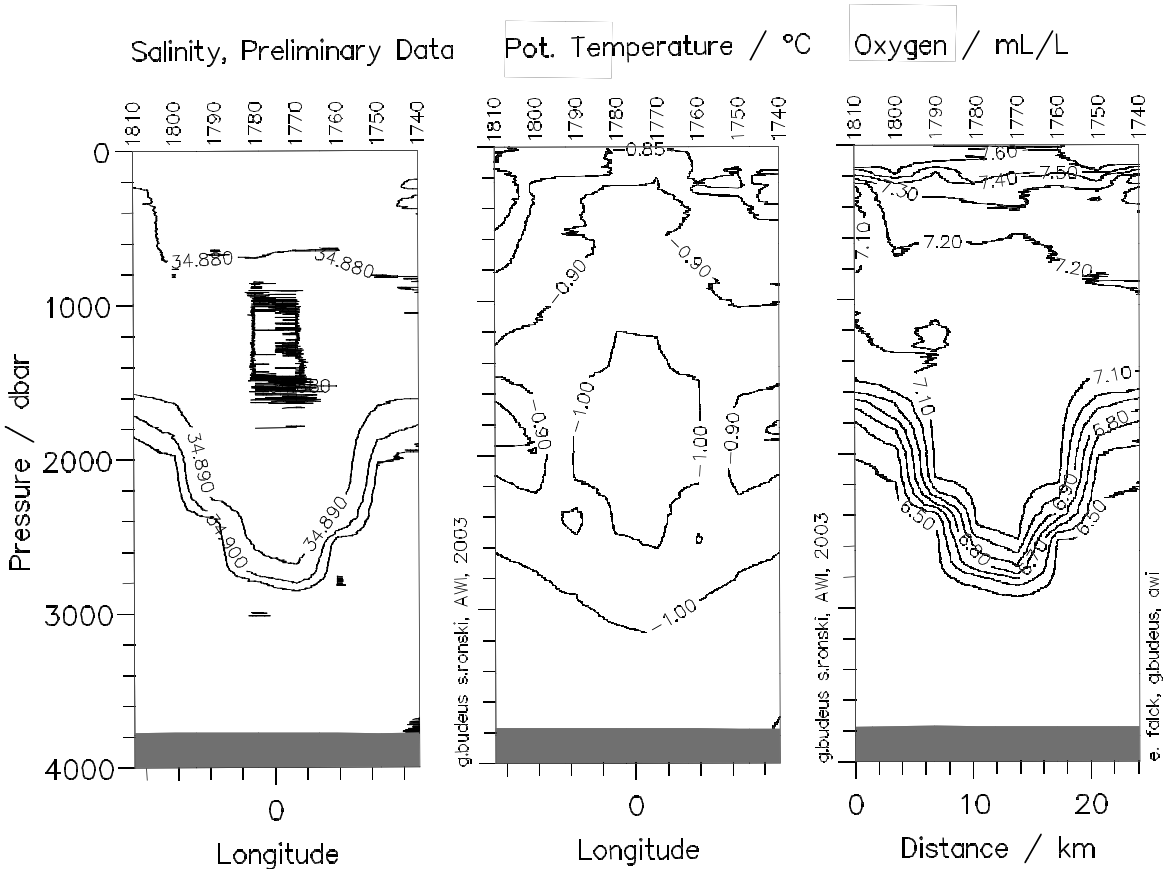

Fig. 2.3.1 Salinity, temperature and oxygen distribution in the convective eddy (SCV)

during the preceeding winter, which may initiate eventually its decay. The extent of the cold temperature core has diminished, the core temperature is not colder than last year, the bottom density step is not found at a deeper level than before, and there is no station with vertically homogeneous profiles.

The general situation was characterized by spring conditions. A stable surface layer had already established, largely due to melting pack ice floes which were encountered already at 2°W. It is difficult to determine the exact depth to which winter convection has proceeded, and this has to be analysed later. At first sight, convection seems to have affected only a few hundred metres. The bottom water temperature increase continued, but in a different fashion than observed before. There is no descend of the temperature maximum, and the lower water column showed higher temperatures than before only within the down most 100 to 200 m. As this effect is presumably due to vertical diffusion, the present situation will allow to investigate its specific contribution to the deep water changes in the Greenland Gyre. This was not feasible during the preceeding years when vertical displacement dominated the time variability.

The work on the East Greenland shelf revealed another striking result. The near surface Arctic outflow normally contains waters of Pacific origin and a silicate maximum below, and both were intended to investigate with this cruise. Although the ship went as close to the Greenland coast as possible (20 miles distance) in spite of severe ice conditions, these types of Polar Waters could not be found. Minimum salinities were just below 34.0, whereas the above mentioned waters typically show salinities of about 33.1. As at the same time the area coverage with old pack ice floes was extreme for the last 10 years, this observation might indicate a change in the Arctic surface current system, resulting in an increasing release of ice through Fram Strait and different surface water paths. This, at present speculative, suggestion is supported by the observed Gelbstoff concentrations which were unusually high and located close to the surface.

2.4 Nutrient distribution in the Greenland Sea

M. Behrends, E. Falck, C. Hartmann, G. Kattner, M. Stürcken (AWI)

The distribution of nutrients is closely connected with physical and planktological investigations. The development of phytoplankton blooms is especially dependent on the availability of nutrients. On the other hand nutrients are good tracers for the identification of water masses. Nitrate and phosphate as well as its ratio are good tracers for the outflow of upper halocline Arctic surface water flowing along the East Greenland continental slope. Part of this water mass is probably of Pacific origin. In addition, high concentrations of silicate are typical for water masses in the East Greenland Current. In comparison with similar transects in former years, the seasonal and interannual variability will be determined.

Nutrient concentrations were measured during the 75°N Greenland Sea transect and across the Greenland shelf and slope. To determine the structure of the water masses along the Greenland coast and slope a second transects was conducted back from the Greenland coast and downwards the slope.

Work at sea

From all water samples, taken with the CTD rosette sampler at different depth, the nutrients - nitrate, nitrite, phosphate and silicate - were determined immediately on board with an Autoanalyser-system according to standard methods. In addition, some samples were taken for dissolved organic carbon determination and some of the material was enriched on C-18 resin for latter characterisation of the chemical structure of dissolved organic material.

Preliminary results

The distribution of phosphate, nitrate and silicate is shown in Fig. 2.4.1. The surface concentrations were relatively high and reflect the typical spring situation where nutrients are not depleted because phytoplankton growth has not been started. The small convective eddy was also detected in the nutrient distribution so that lower concentrations reached deeper than in the surrounding water. Another interesting results was found on the East Greenland shelf and slope were usually enhanced silicate concentrations occurred and water of Pacific origin can be detected by nitrate

to phosphate ratios. During this cruise, however, no comparable signals were found. It might be speculated that the circulation of the upper water masses in the Arctic Ocean was different compared to former years.

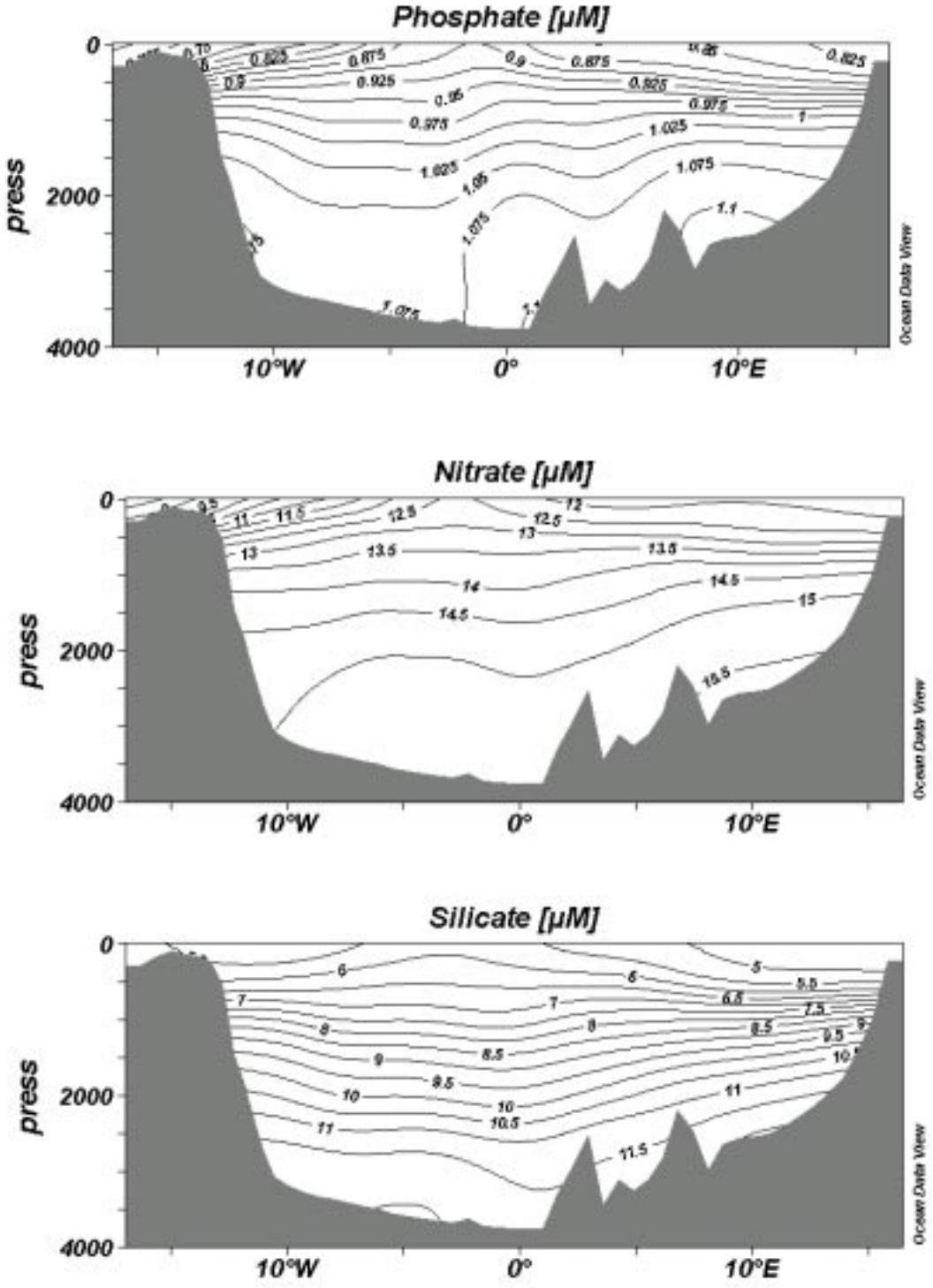

Fig. 2.4.1 Nutrient distribution along the 75°N Greenland Sea transect.

2.5 Transport of terrigenous organic carbon in the East Greenland Current

B. Meon (AWI)

Introduction

The Arctic Ocean holds about 1% of the world's ocean volume but receives a disproportionately large amount (11%) of worldwide river discharge rendering it a unique place to study land-ocean interactions and address the flux and fate of terrigenous organic matter. Eurasian and North American rivers together transport about 23 Tg of dissolved organic carbon (DOC) to the Arctic Ocean. Based on lignin phenol measurements (Opsahl et al. 1999) and more recently fluorescent profiles (Amon et al. 2003) it has been shown that a significant portion of terrigenous dissolved organic material (TDOM) leaves the Arctic Ocean via the East Greenland Current (EGC). However, the current estimates on annual transport of TDOM are based on measurements in August/September thus lacking seasonal resolution. Furthermore, the measurement of specific components of DOM and fluorescence properties of TDOM alone are not sufficient to distinguish between TDOM originating from the Eurasian or North American rivers.

The focus of our current study was to measure fluorescence profiles on the Greenland slope and shelf along the 75°N transect in the EGC. In addition to improving our seasonal resolution of TDOM export estimates to the North Atlantic we intend to use hydrographic data (Budéus and coworkers) and inorganic nutrient measurements (Kattner and coworkers) to link water masses of elevated TDOM concentrations to their Eurasian and/or North American/Pacific origin.

Material and Methods

Fluorescence data were collected in situ using a CTD-mounted probe with a high specificity for TDOM (broad band excitation between 350-460 nm, emission at 550 nm). At selected stations and from various depths DOM was concentrated to conduct lignin phenol measurements in order to calibrate the fluorescent signals against concentrations of vascular plant material that comprises a specific marker for material of terrestrial origin. In short, 10-17 liters of 0.2 µm-filtered seawater was acidified to a pH of 2.5 and passed through a C18 resin using a peristaltic pump and a flow of 1 ml/min. The C18 columns were stored at –20°C for subsequent elution of the adsorbed material with methanol and measurement of lignin phenol oxidation products by gas chromatography-mass spectrometry. Samples for the determination of DOC concentrations were filtered through combusted GF/F-filters and stored frozen in sealed borosilicate ampoules.

Preliminary results

Similar to a previous study (Amon et al. 2003) TDOM fluorescence signals were highest on the Greenland shelf (0.65 relative fluorescence units), decreasing on the steep and narrow slope and reaching almost background levels towards the open Greenland Sea (0.45). The signal intensities were higher than measured before when maximum values on the Greenland shelf at 75°N reached 0.55 fluorescence units (Amon et al. 2003) indicating temporal variations and maybe seasonality in the transport of TDOM with increased TDOM concentrations in spring relative to

summer. A further difference to previous measurements is the location of maximum signal intensities in the depth profiles. Maximum fluorescent values in August/ September were located in a distinct core between 50 and 150 m (Amon et al. 2003). In contrast, fluorescence during this year's measurements was highest at the surface and decreased with depth. Interestingly these changes in the vertical distribution of the fluorescence signals coincide with the absence of a typical Polar Water layer of pacific origin that is characterized by a salinity of about 33 and high silicate concentrations. Thus, the even higher TDOM fluorescence measured this year is likely to derive from material discharged by Eurasian rivers.

In summary there appear to be significant differences between this year's measurements and those conducted in previous years with respect to TDOM concentrations and distribution in the EGC. This may be due to seasonal variations or because of recent changes in the current system of the Arctic Ocean. A closer and quantitative evaluation of the fluorescence data together with nutrient and lignin phenol concentrations will allow a more detailed interpretation of variations in fluxes and the origin of TDOM on the Greenland shelf and slope.

References

Amon, R.M.W., Budéus, G., and B. Meon. 2003. Dissolved organic carbon distribution and origin in the Nordic Seas: Exchanges with the Arctic Ocean and the North Atlantic. Journal of Geophysical Research-Oceans. In press.

Opsahl, S., Benner, R., and R.M.W. Amon. 1999. Major fluxes of terrigenous dissolved organic matter through the Arctic Ocean. Limnology and Oceanography, 4, 2017-2023.

2.6 Carbon isotopes of dissolved organic matter in the Arctic Ocean: disaggregation of the terrestrial component

H. Köhler (IBM)

Introduction

Analyses of the carbon isotopes ^{13}C and ^{14}C in parallel have the potential to disaggregate terrestrial and marine dissolved organic carbon (DOC) due to their distinct isotopic signatures. The combination of the “source indicator” ^{13}C and the “age indicator” ^{14}C will allow us to reconstruct the fate and relative proportion of terrigenous organic matter in the Arctic Ocean and to assess its flux to the North Atlantic. Isotopic studies of this kind are complementary to optical and biomarker approaches, with the advantage that the bulk DOM is taken into account. In previous studies we found the terrigenous DOM on the Arctic shelf to be refractory and of high molecular weight, whereas DOM of marine origin was predominantly abundant as low molecular weight compounds. During this cruise our research activity focused on the isolation and separation of DOM into different molecular weight fractions. The comparison of carbon isotopes in these fractions of different Arctic water masses will enable us to evaluate the dynamics of DOM in the Arctic Ocean in terms of sources and cycling times.

Methods

Five stations representing water masses of the Atlantic, the Greenland Sea and the East Greenland Current were sampled. Large volume water samples (90-120 litres) for analysis of DOM were taken using a CTD-rosette-sampler. Particles were removed by sequential passage through cartridge filters of 3 and 0.2 µm pore size. The filtrate was then separated by membrane filtration into 3 nominal size fractions: HMW DOM (1 kDa to 0.2 µm, high molecular weight DOM), a medium size fraction (0.5 kDa to 1 kDa) and a fraction of low molecular weight (<0.5 kDa). Size fractionation was performed by a tangential-flow ultrafiltration unit (Pall-Rochem) equipped with Osmonics ultrafilters (Desal GE, Desal DK respectively). Immediately following initial fractionation and concentration, retentate samples were desalted using about 5 l of low organic deionized water. Samples for DOC analysis were collected from the <0.2 µm filtrate and each DOM size fraction. Sample retentates of about 2 l were stored frozen at -20°C after desalination.

A newly developed continuous-flow technique based on high-temperature catalytic combustion for further isotope ratio mass spectrometric detection will allow us to determine carbon isotope data directly on the retentate samples as well as on the permeate samples. Thus, our measurements will cover the total size spectrum of dissolved organic matter, even the low molecular weight fraction, which escaped isotopic measurements in seawater so far.

2.7 Ocean Optics

J. Schwarz, I. Kolar (AWI)

Introduction

Ocean colour satellites, such as SeaWiFS and MoDIS, offer unrivalled temporal and spatial coverage of the surface ocean. These data provide the basis for global estimates of parameters such as phytoplankton biomass and particulate organic carbon, as well as shedding light on seasonal changes and many other phenomena. However, no signal is received in the polar winter or in the presence of large-scale cloud and ice cover, and the signal is especially difficult to interpret when small, sub-pixel-sized clouds or ice fragments are present. In the Atlantic Arctic sector, the spring phytoplankton bloom occurs at the ice edge, making it difficult for satellite sensors to see. A further drawback to ocean colour products is their current reliance on empirical algorithms which are based on measurements in the mid-latitudes. This means that any variability in pigment composition or depth of the chlorophyll maximum, for example, is not included in the algorithms, possibly leading to unrealistic parameter estimates and leaving the ocean colour product quality uncertain.

During this leg of the cruise we worked in collaboration with the group from Scripps Institute of Oceanography: Malgorzata Stramska, Ben Allison and Slawomir Kaczmarek (on loan from the Polish Academy of Sciences Institute of Oceanology, Poland). While we focused on spatial coverage, the Scripps group used profiling instruments to gather information about variability with depth. These datasets should be viewed as complementary.

Aims

Our aims during ARK XIX/2 were:
- to gather as many suites of optical measurements as possible, to add to the sparse knowledge of optical parameters in this region and give a good statistical basis for evaluating algorithm performance during the Arctic springtime.
- to sample the regions with low-percentage ice-cover to estimate errors in satellite data in the presence of sub-pixel ice,
- to sample the ice-covered regions to judge the quality of global estimates of, for example, productivity, which are based solely on ocean colour data.

Methods

Water was taken at 10 m from the CTD where possible. Owing to high demand for water from different groups, samples were occasionally taken from the flow-through supply at 10.7 m, or using a bucket to gather surface water. Samples were taken for:
concentration of phytoplankton pigments (HPLC),
absorption by phytoplankton pigments,
concentration of dissolved, organic carbon,
absorption by coloured, dissolved organic matter,
concentration of organic and inorganic suspended particulates,
particle size distribution (Coulter Counter),
concentration of particulate organic carbon,
concentration of bacteria, and
phytoplankton taxonomy.

Phytoplankton Pigments: Samples were stored in opaque bottles. Between 500 ml and 5 litre aliquots were filtered through 25 mm GF/F filters, which were blotted immediately after filtration was complete, and stored in a liquid nitrogen dewar in 2 ml cryovials. Duplicate and, when possible, triplicate samples were stored in separate dewars. The samples were returned to Bremerhaven for analysis using HPLC.

Absorption by Phytoplankton Pigments: Samples were treated as for phytoplankton pigments. The filters were placed in 27 mm diameter tissue capsules and stored in a liquid nitrogen dewar. At two stations, a series of filtrations was carried out with aliquots of 0 to 1.5 litres of seawater (0.2 µm filtered seawater was filtered for the blank). The purpose of these experiments was to provide information on the particle concentration effect when measuring absorption, for which a correction, the beta-correction factor, must be applied.

Absorption by Coloured, Dissolved Organic Matter and Dissolved Organic Carbon Concentrations: Samples were collected as for phytoplankton pigments. Using a ‚contact free' 47 mm glass filtration unit (Sartorius), two 300 to 500 ml aliquots of sample water were filtered through a fresh 0.2 µm membrane filter to rinse the sample collection flask. A third aliquot of sample was filtered and used firstly to rinse thrice and then to fill two 50 ml brown glass sample bottles. For DOC, the sample bottle was half-full, and the bottles were frozen at –25°C, then stored at –10°C. CDOM samples were stored at 4°C.

Concentration of Suspended Particulate Matter (organic/Inorganic): Samples were collected as for phytoplankton pigments. Between 1 and 10 litre aliquots were

filtered through precombusted and weighed 47 mm GF/F filters. After filtration, the filters were stored at –25°C. When possible, triplicate samples were taken, together with a blank.

Concentration of Particulate Organic Carbon: Samples were collected as for phytoplankton pigments. Between 0.5 and 5 litre aliquots were filtered through pre-combusted, 25 mm diameter GF/F filters. The filters were folded and stored in foil wrappings at –25°C. Blanks were taken every 1 to 5 days.

Particle Size Distribution: Samples were collected as for phytoplankton pigments. Aliquots of 250 ml were stored in brown glass bottles, conserved with Lugol's iodine, at room temperature.

Taxonomy: Samples were collected as for phytoplankton pigments. Aliquots of 100 or 250ml were preserved with Lugol's iodine.

Concentration of Bacteria: Samples were collected as for phytoplankton pigments. After rinsing a brown glass bottle three times with sample water, aliquots of 100 ml were preserved using 10 drops of 37% formaldehyde and stored at 4°C.

All samples will be analysed at the home laboratory. Table 2.7.1 indicates which parameters were sampled at each station. All samples are from one or more CTD rosette bottles closed at approximately 10 m depth, except: Stations 168, 169, 174, 175 – taken from the surface using a bucket, and Stations 151, 158, 162, 199, 211, 212, 225, 228, underway 1-13 – all or partially taken from the ship's surface supply (10.7 m).

Table 2.7.1 Parameters sampled at each station during ARK XIX/2

Date	Time (UTC)	Station	HPLC	APHY	ACDOM	DOC	SPM	POC	PSD	TAX	BAC	PHO
25.04.	14:40	138	x	x	x		x		x	x		
		139	x	x	x	x	x	x	x	x		
		140	x	x	x	x	x	x	?	?		
26.04.	05:00	141	x	x	x	x	x	x	x	x		
		142	x	x	x	x	x	x	x	x		
		143	x	x	x	x	x	x	x	x		
		144	x	x	x	x	x	x	x	x		
		145	x	x	x	x	x	x	x	x		
	10:20	146	x	x	x	x	x	x	x	x		
27.04.	01:30	147	x	x	x	x	x	x	x	x		
	04:15	148	x	x	x	x	x	x	x	x		
	07:30	149	x	x	x	x	x	x	x	x		
	14:30	150	x	x	x	x	x	x	x	x		
	15:45	151	x	x	x	x	x	x	x	x		
	18:30	152	x	x	x	x	x	x	x	x		
	21:00	153	x	x	x	x	x	x	x	x		
	22:58	154	x	x	x	x	x	x	x	x		
28.04.	01:40	155	x	x	x	x	x	x	x	x		
	04:30	156	x	x	x	x	x		x	x		
	08:45	157	x	x	x	x	x	x	x	x		
	14:00	158	x	x	x	x	x	x	?	?		
	17:00	159	x	x	x	x	x	x	x	x		
		160	x	x	x	x	x	x	?	?		
	21:40	161	x	x	x	x	x	x	x	x		
29.04.	00:40	162	x	x	x	x	x	x	x	x		
	03:50	163	x	x	x	x	x	x	x	x		
	08:30	164	x	x	x	x	x	x	x	x		

Date	Time (UTC)	Station	HP LC	AP HY	AC DOM	DOC	SPM	POC	PSD	TAX	BAC	PHO
	16:00	165	x	x	x	x	x	x	x	x		
30.04.	13:30	168	x	x	x	x	x	x	x	x		
	16:00	169	x	x	x	x	x	x	x	x		
	19:00	170	x	x	x	x	x	x	x	x		
	23:40	172	x	x	x	x	x	x	x	x		
	02:40	173	x	x	x	x	x	x	x	x		
01.05.	06:15	174	x	x	x	x	x	x	x	x		
	11:30	175	x	x	x	x	x	x	x	x		
	14:45	176	x	x	x	x	x	x	x	x		
	20:00	178	x	x	x	x	x	x	x			
02.05.	01:00	180	x	x	x	x	x	x	x			
		182	x	x	x	x	x	x	x	x		
	19:20	184	x	x	x	x	x	x	x	x	x	
	21:40	185	x	x	x	x		x	x	x		
03.05.	01:00	186	x	x	x	x	x	x	x	x		
	20:30	189-2	x	x	x	x	x	x	x	x		
04.05.	02:15	190	x	x	x	x		x	x	x		
	05:30	191	x	x	x	x	x	x	x	x		
	12:00	192	x	x	x	x	x	x	x	x		
	16:15	193	x	x	x	x	x	x	x	x		
	19:40	194	x	x	x	x	x	x	x	x		
	21:10	195	x	x	x	x	x	x	x	x		
05.05.	00:40	196	x	x	x	x	x	x	x	x		
	04:15	197	x	x	x	x	x	x	x	x	x	
	11:15	198	x	x	x	x	x	x	x	x	x	
	17:45	199	x	x	x	x	x	x	x	x	x	
	20:30	200	x	x	x	x	x	x	x	x	x	
	22:50	201	x	x	x	x	x	x	x	x	x	
06.05.	01:50	202	x	x	x	x	x	x	x	x	x	
	04:55	203	x	x	x	x	x	x	x	x	x	
	08:30	204	x	x	x	x	x	x	x	x	x	
	10:45	205	x	x	x	x	x	x	x	x	x	
	13:20	206	x	x	x	x	x		x	x	x	
	17:00	207	x	x	x	x	x	x	x	x	x	
	19:00	208	x	x	x	x	x	x	x	x	x	
	21:20	209	x	x	x	x	x		x	x	x	
07.05.	01:00	210	x	x	x	x	x	x	?	?	x	
	08:30	211	x	x	x	x	x	x	x	x	x	
	13:30	212	x	x	x	x	x		x	x	x	
		213							x		x	
		214	x	x	x	x	x		x	x	x	
	21:15	215	x	x	x	x	x		x	x	x	
	22:35	216	x	x	x	x	x		x	x	x	
08.05.	00:16	218	x	x	x	x	x		x	x	x	
	01:20	219	x	x	x	x	x		x	?	?	
	03:10	221	x	x	x	x	x		x	x	x	
	04:35	222	x	x	x	x	x		x	x	x	
	05:50	223	x	x	x	x	x		x	x	x	
	08:20	224	x	x	x	x	x		x	x	x	
	10:20	225	x	x	x	x	x		x	x	x	
	13:00	226	x	x	x	x	x	x	x	x	x	
	16:25	227	x	x	x	x	x	x	x	x	x	
	20:40	228	x	x	x	x	x	x	x	x	x	
	23:30	229	x	x	x	x	x	x	x	x	x	
09.05.	02:30	230	x	x	x	x	x	x	x	x	x	
	06:00	231	x	x	x	x	x	x	x	x	x	
	09:40	232	x	x	x	x	x	x	x	x	x	

Date	Time (UTC)	Station	HPLC	APHY	ACDOM	DOC	SPM	POC	PSD	TAX	BAC	PHO
	12:00	Uway1	x	x	x	x	x	x	x	x	x	x
	14:00	Uway2	x	x	x	x	x	x	x	x	x	x
	18:00	Uway3	x	x	x	x	x	x	x	x	x	x
	22:00	Uway4	x	x	x	x	x	x	x	x	x	x
	02:00	Uway5	x	x	x	x	x	x	x	x	x	x
10.05.	06:00	Uway6	x	x	x	x	x	x	x	x	x	x
	10:00	Uway7	x	x	x	x	x	x	x	x	x	x
	14:00	Uway8	x	x	x	x	x	x	x	x	x	x
	18:00	Uway9	x	x	x	x	x	x	x	x	x	x
	22:00	Uway10	x	x	x	x	x	x	x	x	x	x
11.05.	02:00	Uway11	x	x	x	x	x	x	x	x	x	x
	06:00	Uway12	x	x	x	x	x	x	x	x	x	x
	10:00	Uway13	x	x	x	x	x	x	x	x	x	x

2.8 Optical measurements

M. Stramska (USC), D. B. Allison (SIO), S. Kaczmarek (IOPAS)

Our operational objective during the cruise was to carry out a set of in-water optical measurements and to collect discrete water samples for various biochemical analyses (more information about collected data is given below). This work was done in collaboration with Dr. Jill Schwarz from AWI during the second leg of ARK XIX cruise. Our near-future goal is to use the collected data to develop sound bio-optical relationships for the north polar regions. Such bio-optical relationships will be useful for quantitative interpretation of in-situ and satellite optical data in terms of the concentration of optically active water components such as chlorophyll (Chl), particulate organic carbon (POC) and total suspended matter (TSM). Note, that present global ocean colour remote sensing algorithms are based largely on data sets collected in mid- and low-latitudes and there is a concern that satellite remote sensing of phytoplankton biomass in polar regions may be subject to significant errors. Therefore we plan to use our data for validation of the standard ocean colour algorithms in the investigated region. We also expect that our data set will allow us to design refined and new algorithms, and to study the mechanisms driving the observed bio-optical variability. For example, one of our efforts will focus on the development of algorithms for POC determination from satellite data. While pigment algorithms are a routine application of ocean colour remote sensing, the capability to estimate POC from optical remote sensing represents a relatively new idea. Because carbon is of direct interest for the studies on biogeochemical cycles in the oceans, we believe that our goal to develop remote sensing capabilities for estimating POC will be of major significance for advancing our understanding of the role of the oceans in global climate change.

Measurements

The overall cruise schedule allowed for one full optical station and at least two additional short optical stations per day. Data collected at these stations included in water optical measurements with our profiling instruments and filtration of water samples from the ship's CTD for analysis of various water constituents. These are all described in more detail below.

During the full optical station we made vertical profiles using a freefall radiometer (SPMR, Satlantic – RAD on the cruise station logs) for measurements of spectral downwelling irradiance (E_d) and upwelling radiance (L_u) at 13 wavebands (339, 380, 411, 443, 470, 490, 510, 531, 555, 590, 619, 666, and 684 nm). We also measured vertical profiles of the physical and inherent optical water properties with the Multisensor Datalogger System (MDS– OP on the cruise station logs). This system includes a SeaBird Sealogger 25 with temperature, conductivity, and pressure sensors, two single-wavelength (488 and 660 nm) beam transmissometers (WetLabs), chlorophyll fluorometer (WetLabs), Quantum Scalar Irradiance (PAR) sensor (QSP-200PD, Biospherical), the spectral backscattering meter Hydroscat-6 (HobiLabs) allowing determination of backscattering coefficient (b_b) at six wavelengths (442, 470, 555, 589, 620, and 671 nm), and two a-beta (HobiLabs) instruments for measurements of total absorption (a) and backscattering coefficients at one waveband each (420 and 510 nm). Typically, the SPMR downcasts ended at 60-m and the MDS downcast ended at 150-m depth.

Short optical stations included vertical profiles of physical and inherent optical water properties with the MDS package in surface water (30-50 m). In addition to the regular short optical stations we were able to increase the frequency of these casts on the transect out of the Greenland shelf. In this case the MDS casts were done on every regular ship's CTD station (PS64/214 - PS64/232) down to 100-m depth.

At most of the optical stations discrete water samples were taken from the ship's CTD bottles at selected depths within the euphotic zone for various analyses. Typically during the full optical station discrete water samples were collected at 5 depths while only 2 depths were sampled at the short optical stations. In addition to the optical stations, we sampled water from the ship's flow-through sea water system (ca. 10 m depth) at opportune times. In particular, we observed spring bloom conditions at the ice edge, and water was sampled from the ship's flow-through water supply for some time after the regular CTD stations ended.

All the discrete water samples will be analysed at the appropriate facilities at our home institutions. Particulate ($a_p(\lambda)$) and phytoplankton ($a_{ph}(\lambda)$), absorption spectra from 300 to 800 nm will be measured with a double-beam bench-top spectrophotometer using a filter-pad technique. The dry weight of total suspended matter (*TSM*) will be obtained by standard gravimetric technique. Standard procedures will be used to measure pigments (HPLC and fluorometry) and POC (combustion of dry sample filters). At selected stations water samples were also preserved for microscopic analysis of plankton. A list of optical stations and their geographical positions are shown in Table 2.8.1 and Figure 2.8.1.

Additionally, in few cases when we observed clear sky conditions (during a station or when ship was underway) we made above-water optical measurements of direct sun radiance with a portable hand-held sun photometer MicroTops (Solar Light). This instrument includes 5 wavebands: 440, 500, 675, 870, and 940 nm, and allows the determination of atmospheric aerosol optical thickness for proper correction of direct atmospheric transmittance. Aerosol optical thickness at the time of satellite overpass is essential for verifying the atmospheric correction of ocean colour.

Preliminary Results

Full interpretation of our data will be only possible after we finish processing the optical and physical data from the vertical profiles and discrete water samples are analysed in the appropriate facilities. However, preliminary results indicate that in the open ocean waters we observed mostly low chlorophyll concentrations characteristic of pre-bloom conditions. Higher concentrations of phytoplankton were present only at the ice edge on the way into and out of the East Greenland Current. Examples of concurrent vertical profiles of water temperature, salinity, density, fluorescence, and beam transmission at 488 and 660 nm are shown in Figures 2.8.2 – 2.8.7. Stations shown in Figures 2.8.2 – 2.8.5 were collected on the 75°N transect, while stations shown in Figures 2.8.6 and 2.8.7 represent bloom conditions observed on the ice edge on the way out of the Greenland shelf. Interestingly, it is evident from the data shown in Figures 2.8.2 – 2.8.7 that there is a good correspondence between the physical and optical features in the vertical profiles observed in surface waters of the various oceanic regions visited during our cruise.

Table 2.8.1 List of full and short optical stations.

SIO Station Number	AWI Station Number	Date Time [GMT]	Latitude [°]	Longitude [°]
full stations				
1	PS64/138	4/25/2003 14:04	75.9183	13.8742
2	PS64/144	4/26/2003 10:51	74.9985	12.5977
5	PS64/150	4/27/2003 11:21	75.0002	8.7365
8	PS64/157	4/28/2003 08:44	74.9973	4.2347
11	PS64/164	4/29/2003 08:30	75.0003	-0.3038
18	PS64/189	5/03/2003 20:25	75.0010	-4.1233
20	PS64/192	5/04/2003 10:05	75.0012	-6.0660
22	PS64/198	5/05/2003 09:27	75.0023	-9.9283
29	PS64/213	5/07/2003 15:47	74.9978	-16.0050
41	PS64/225	5/08/2003 09:18	74.7552	-13.0620
short stations				
12	PS64/165	4/29/2003 14:17	74.9987	-0.9333
13	PS64/168	4/30/2003 11:25	74.7682	-0.1278
14	PS64/169	4/30/2003 14:34	74.7995	-0.1295
16	PS64/175	5/01/2003 09:45	74.8418	0.3132
23	PS64/199	5/05/2003 14:58	75.9990	-10.5877
24	PS64/204	5/06/2003 07:37	74.9783	-12.4870
25	PS64/205	5/06/2003 10:06	74.9900	-12.6292
26	PS64/207	5/06/2003 17:00	74.9547	-13.2487
27	PS64/211	5/07/2003 08:23	75.0032	-15.6675
28	PS64/212	5/07/2003 13:10	74.9987	-16.3323
30	PS64/214	5/07/2003 17:40	74.9830	-15.6947
32	PS64/215	5/07/2003 20:56	74.9708	-15.3545
33	PS64/216	5/07/2003 22:35	74.9215	-14.9567
34	PS64/217	5/07/2003 23:23	74.9277	-14.6838
35	PS64/219	5/08/2003 01:15	74.9353	-14.1185
36	PS64/220	5/08/2003 02:15	74.9072	-13.8538
37	PS64/221	5/08/2003 03:09	74.8543	-13.6178
38	PS64/222	5/08/2003 04:35	74.8037	-13.2275
39	PS64/223	5/08/2003 05:31	74.7870	-13.1695
40	PS64/224	5/08/20030 7:59	74.7713	-13.1330
42	PS64/226	5/08/2003 11:59	74.7785	-12.8190
43	PS64/227	5/08/2003 13:57	74.7223	-12.6920
43	PS64/227	5/08/2003 13:57	74.7223	-12.6920
44	PS64/228	5/08/2003 19:42	74.6613	-12.4815
45	PS64/229	5/08/2003 22:09	74.6270	-12.2085
46	PS64/230	5/09/2003 01:05	74.5838	-11.8910
47	PS64/231	5/09/2003 04:26	74.5000	-11.3940
48	PS64/232	5/09/2003 07:59	74.3950	-10.8620

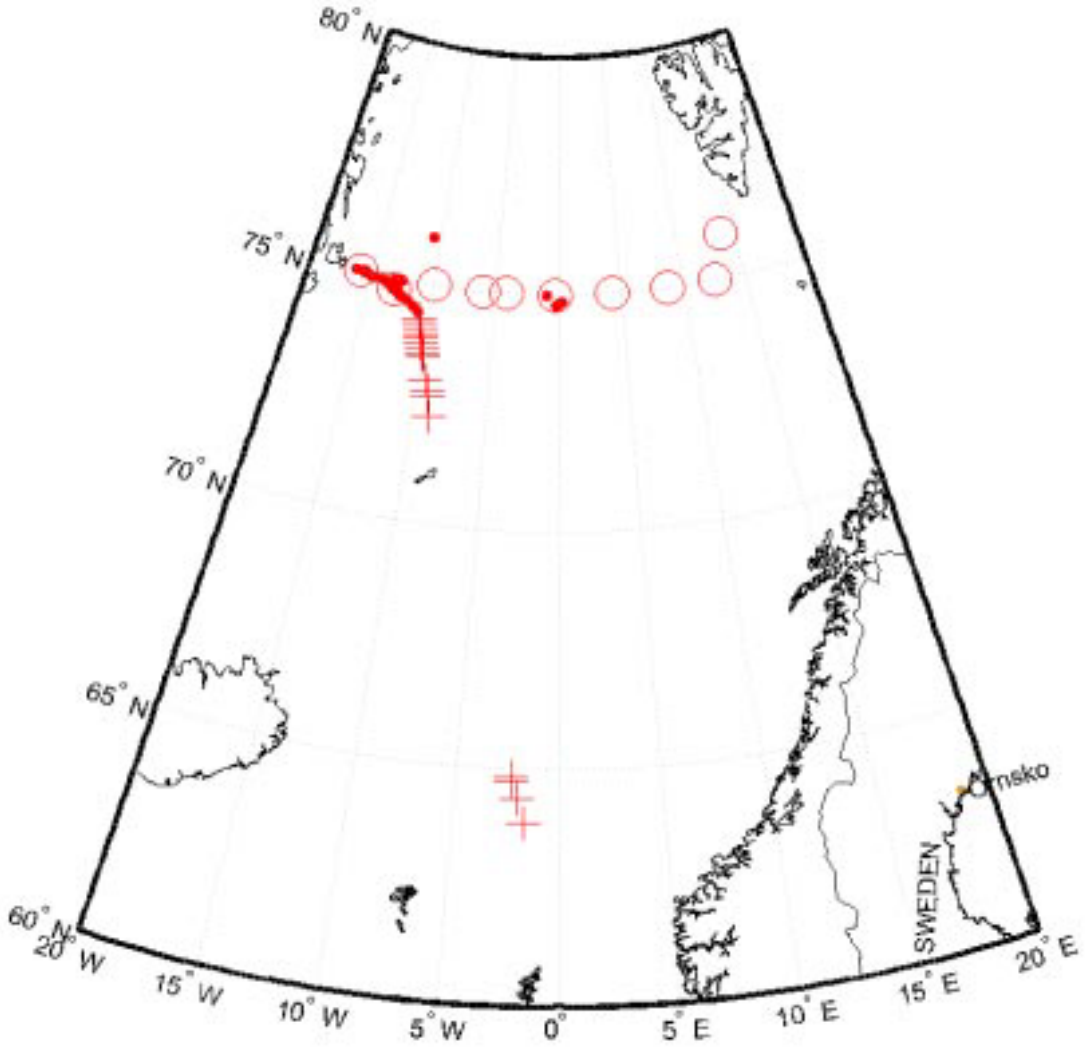

Figure 2.8.1 Map showing the locations of the optical stations covered by the Scripps group. Full optical stations are indicated by circles, short stations by dots, and the ship's positions on the way back to Bremerhaven when water samples were collected from the flow-through sea water system are indicated by crosses.

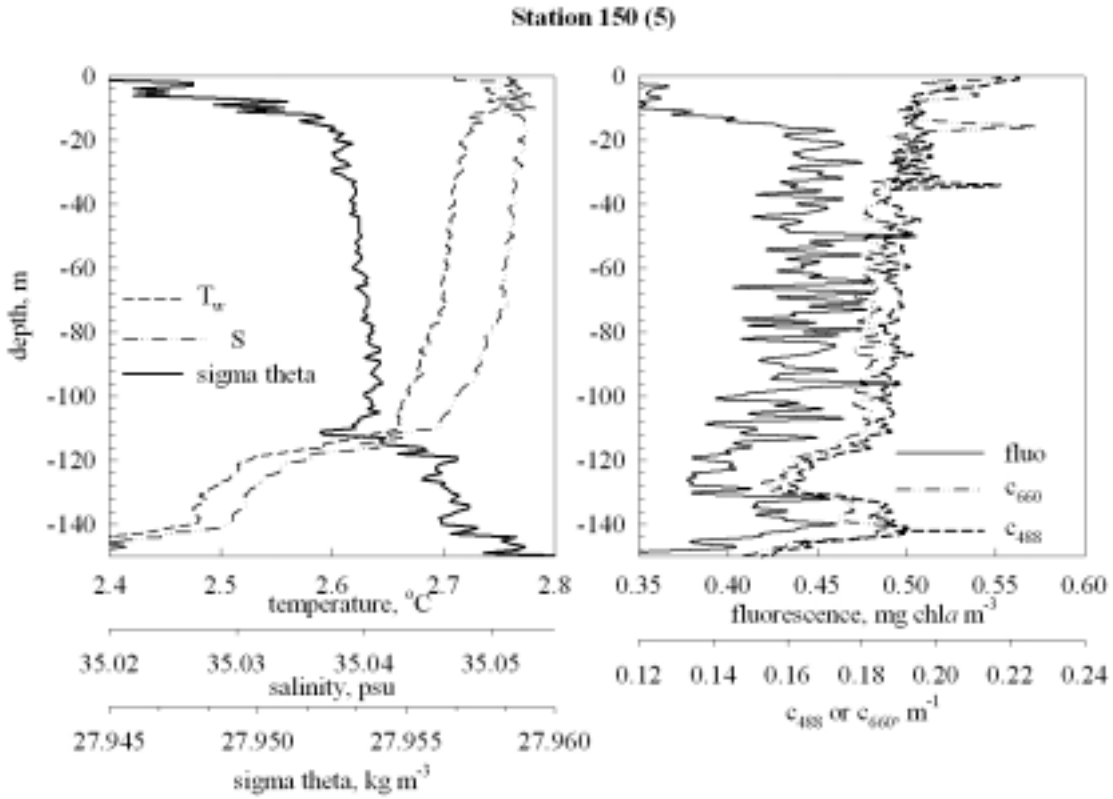

Figure 2.8.2 Vertical profiles of water temperature (T_w), salinity (S), density (sigma theta), beam attenuation at 488 nm (c_{488}) and 660 nm (c_{660}), and fluorescence (fluo) measured at station 150 (75.001°N, 8.7365°E). The number in parenthesis indicates Scripps station number (SIO station 5). Fluorescence has been tentatively converted to mg chl *a* m^{-3} based on the fluorometer calibrations from our previous experiments.

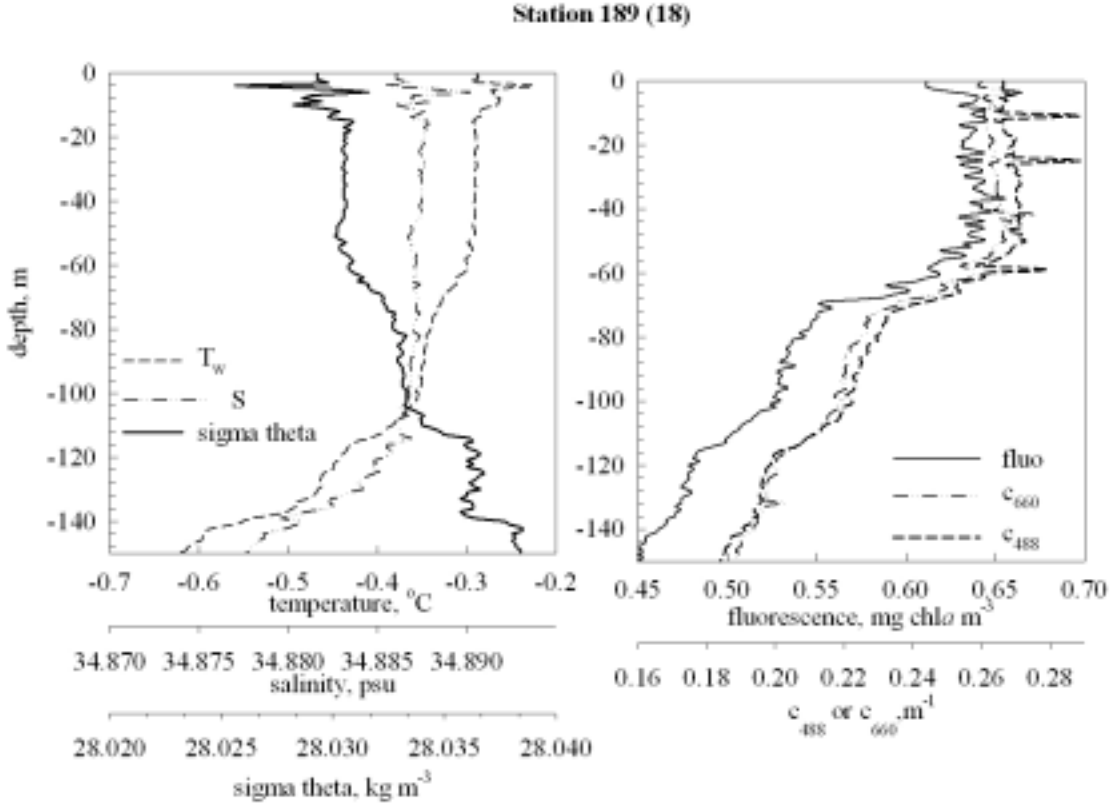

Figure 2.8.3 As in Figure 2.8.2, but for station 189 (75.001°N, 4.1233°E).

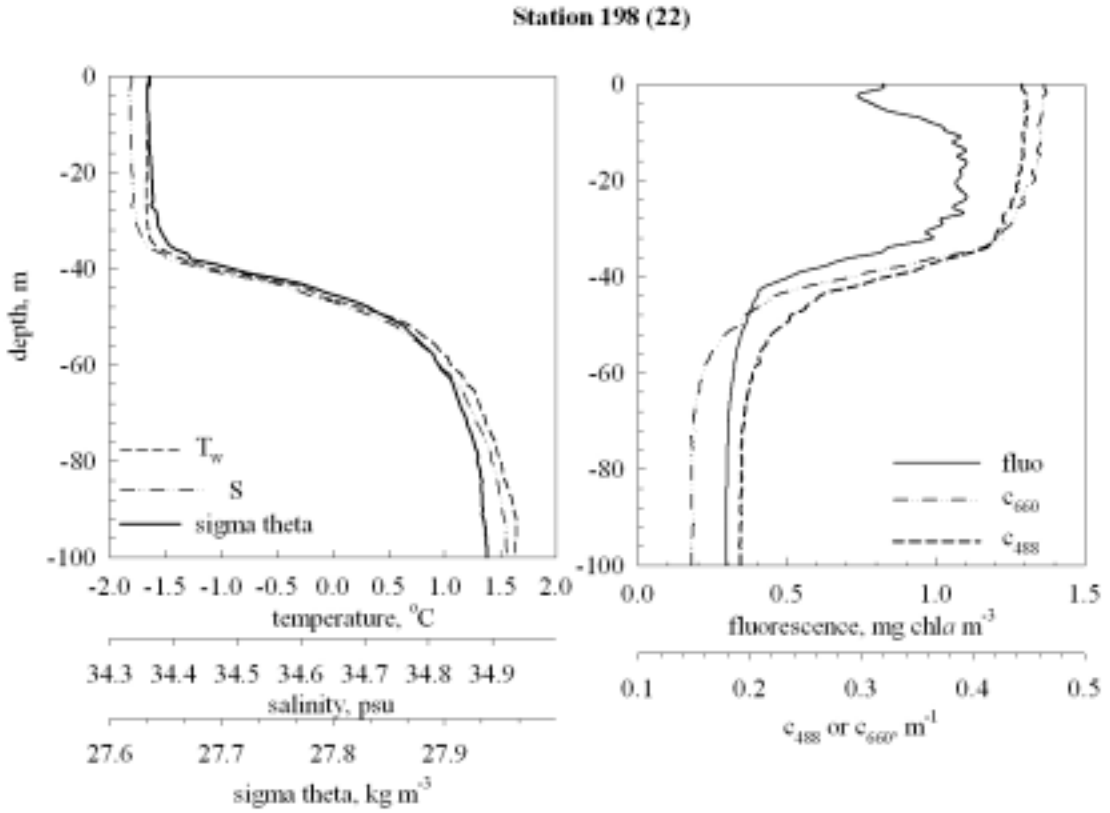

Figure 2.8.4 As in Figure 2.8.2, but for station 198 (75.0023N, 9.9283W).

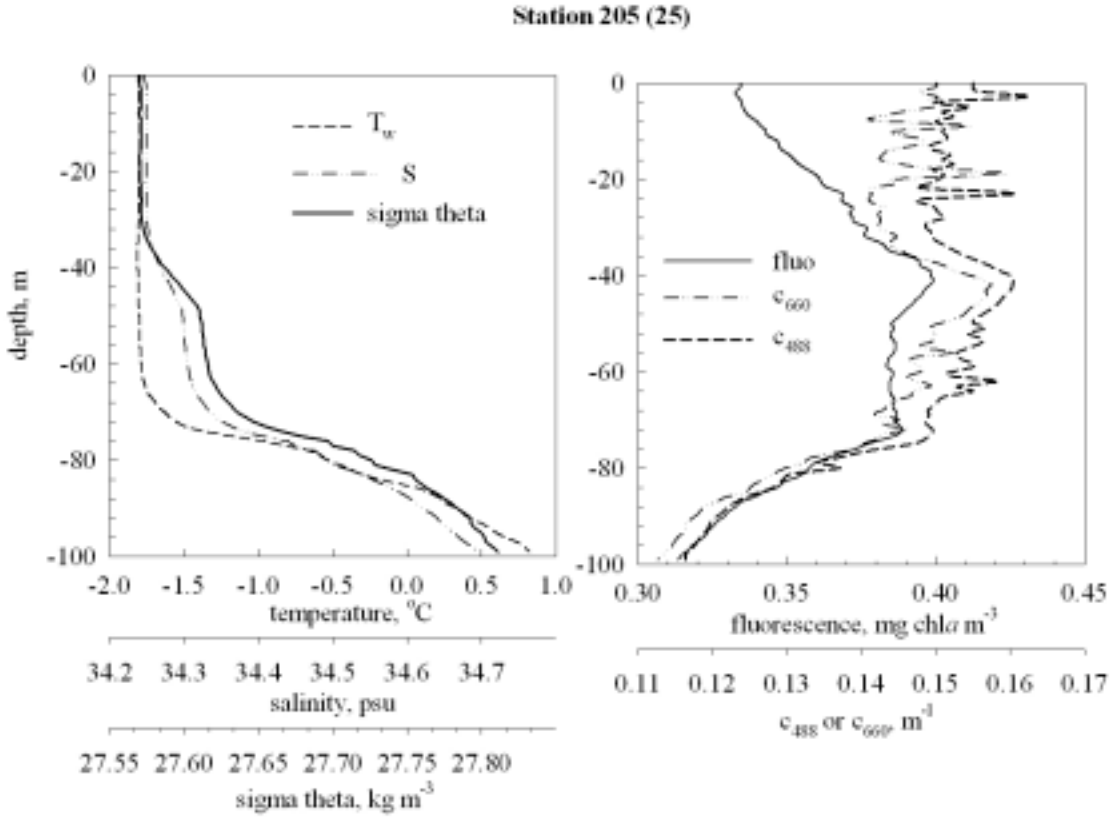

Figure 2.8.5 As in Figure 2.8.2, but for station 205 (74.99N, 12.629W).

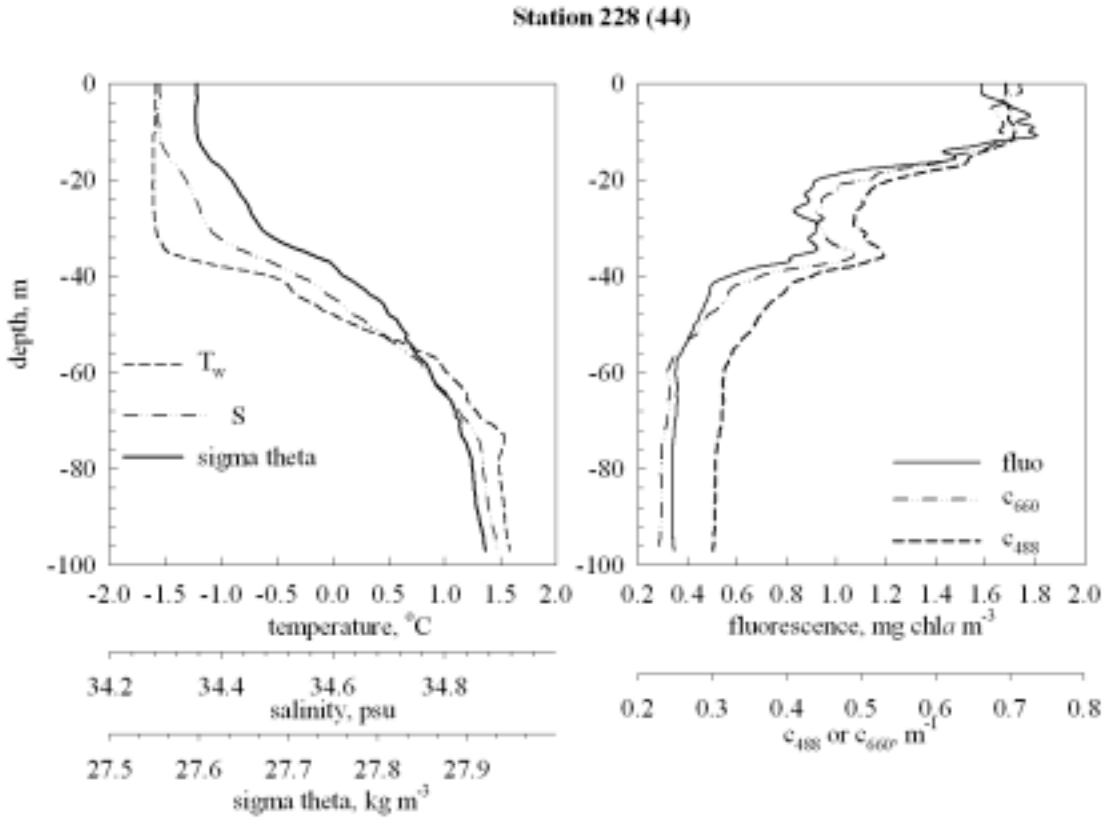

Figure 2.8.6 As in Figure 2.8.2, but for station 228 (74.661N, 12.4815W).

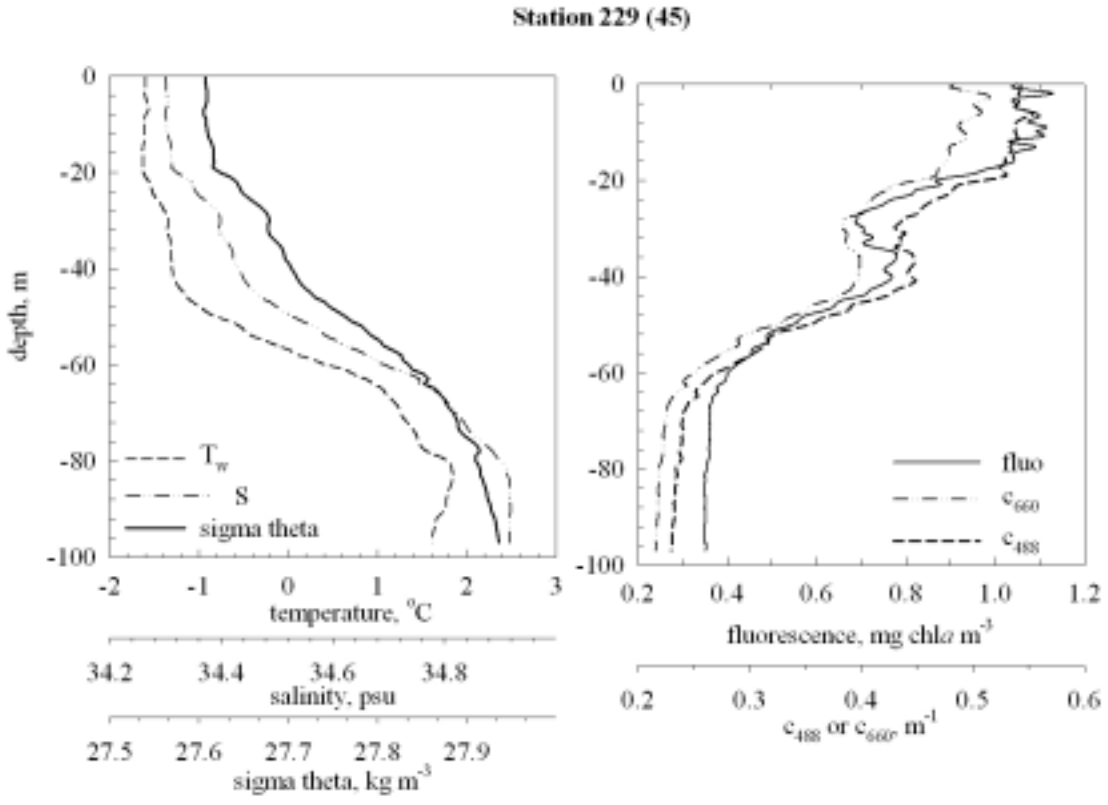

Figure 2.8.7 As in Figure 2.8.2, but for station 229 (74.627N, 12.2085W).

2.9 Zooplankton

R. Alheit, U. Babst (AWI)

To further clarify the reproductive biology of calanoid copepods from the Greenland Sea a number of zooplankton net samples were taken. A multiple opening and closing net with 150 µm mesh size was employed down to a depth of 2200 m, and the water column sampled vertically at 9 given depths, in both Atlantic and Arctic water masses.

Parallel catches were made down to 200 m, using a fine mesh (55 µm) Nansen Net for population genetic studies. Daily fine mesh (55 µm) Nansen samples, (a total of 14), were taken to collect eggs and young larval stages. Both sets of samples were conserved for further analysis. For gonad maturity and egg production investigation daily samples were taken using a 310 µm mesh size Bongo net. Fifty female *Calanus hyperboreus* were removed from each Bongo catch (total catches = 11) and kept in the laboratory as a time serious for in-situ-investigation of gonad maturity and egg production.

Additional experiments with differing food regimes were started to compare gonadal development of *C. hyperboreus* females from 2 different water masses. Further samples were taken for carbon and nitrogen analyses.

2.10 Station list

Station	Date	Time (UTC)		Position Lat	Position Lon	Depth [m]	Gear Abbreviation
		Start	End				
138	25.04.03	14:04	15:22	75° 55.10' N	13° 52.45' E	822.4	CTD/RO, OP, RAD
139	25.04.03	22:38	23:00	74° 59.90' N	15° 50.23' E	266.9	CTD/RO
140	26.04.03	00:21	01:16	74° 59.88' N	15° 8.33' E	1052.0	CTD/RO
141	26.04.03	02:23	03:21	75° 0.08' N	14° 29.95' E	1449.0	CTD/RO
142	26.04.03	04:30	06:44	75° 0.02' N	13° 51.76' E	1811.0	CTD/RO, BO, NN
143	26.04.03	08:09	09:31	75° 0.01' N	13° 13.14' E	2023.0	CTD/RO, OP, RAD
144	26.04.03	10:51	13:13	74° 59.91' N	12° 35.86' E	2191.0	CTD/RO
145	26.04.03	14:33	20:50	75° 0.04' N	11° 55.82' E	2345.0	CTD/RO, OP, NN, MN
146	26.04.03	22:20	00:03	74° 59.84' N	11° 17.97' E	2467.0	CTD/RO
147	27.04.03	01:27	02:58	75° 0.05' N	10° 38.24' E	2548.0	CTD/RO
148	27.04.03	04:15	05:43	74° 59.96' N	9° 59.82' E	2595.0	CTD/RO
149	27.04.03	07:11	09:48	75° 0.11' N	9° 22.81' E	2610.0	CTD/RO, OP, NN, BO
150	27.04.03	11:21	13:25	75° 0.01' N	8° 44.19' E	2683.0	CTD/RO, OP, RAD
151	27.04.03	14:42	16:41	74° 59.89' N	8° 4.62' E	3538.0	CTD/RO, OP
152	27.04.03	17:47	19:16	74° 59.97' N	7° 25.61' E	2489.0	CTD/RO
153	27.04.03	20:24	21:44	75° 0.11' N	6° 46.94' E	2280.0	CTD/RO
154	27.04.03	22:58	00:26	74° 59.98' N	6° 7.59' E	2876.0	CTD/RO
155	28.04.03	01:39	03:13	74° 59.93' N	5° 29.76' E	3127.0	CTD/RO
156	28.04.03	04:29	07:26	74° 59.99' N	4° 51.58' E	3275.0	CTD/RO, Op, NN, BO
157	28.04.03	08:44	11:03	74° 59.84' N	4° 14.08' E	3140.0	CTD/RO, OP, RAD
158	28.04.03	12:17	14:14	74° 59.98' N	3° 34.86' E	3492.0	CTD/RO, OP
159	28.04.03	15:37	17:18	74° 59.84' N	2° 55.77' E	2550.0	CTD/RO
160	28.04.03	18:48	20:31	74° 59.92' N	2° 17.04' E	2966.0	CTD/RO
161	28.04.03	21:39	23:28	75° 0.03' N	1° 38.03' E	3164.0	CTD/RO
162	29.04.03	00:39	02:44	75° 0.03' N	0° 59.37' E	3791.0	CTD/RO
163	29.04.03	03:53	07:12	74° 59.94' N	0° 21.01' E	3791.0	CTD/RO, OP, NN, BO
164	29.04.03	08:30	13:24	75° 0.02' N	0° 18.23' W	3788.0	CTD/RO, OP, RAD
165	29.04.03	14:17	16:44	74° 59.92' N	0° 56.00' W	3747.0	CTD/RO, OP
166	29.04.03	17:28	06:54	74° 59.98' N	1° 15.00' W	3660.0	XBT
167	30.04.03	07:54	10:28	74° 44.17' N	0° 7.74' W	3619.0	CTD/RO, NN
168	30.04.03	11:25	13:52	74° 46.09' N	0° 7.67' W	3801.0	CTD/RO, OP
169	30.04.03	14:34	16:45	74° 47.97' N	0° 7.77' W	3782.0	CTD/RO, OP
170	30.04.03	17:30	19:43	74° 50.08' N	0° 7.58' W	3796.0	CTD/RO
171	30.04.03	20:36	22:49	74° 51.96' N	0° 7.51' W	3790.0	CTD/RO
172	30.04.03	23:37	01:47	74° 54.00' N	0° 7.40' W	3790.0	CTD/RO
173	01.05.03	02:38	04:44	74° 56.01' N	0° 7.56' W	3790.0	CTD/RO
174	01.05.03	06:14	09:03	74° 50.43' N	0° 26.79' E	3795.0	CTD/RO, OP, NN, BO
175	01.05.03	09:45	12:15	74° 50.51' N	0° 18.79' E	3792.0	CTD/RO, OP
176	01.05.03	12:53	14:51	74° 50.48' N	0° 11.50' E	3793.0	CTD/RO
177	01.05.03	15:30	17:37	74° 50.54' N	0° 3.48' E	3792.0	CTD/RO
178	01.05.03	18:07	20:03	74° 50.51' N	0° 3.91' W	3792.0	CTD/RO
179	01.05.03	20:35	22:36	74° 50.51' N	0° 11.54' W	3790.0	CTD/RO
180	01.05.03	23:17	01:11	74° 50.54' N	0° 18.65' W	3795.0	CTD/RO
181	02.05.03	02:02	03:52	74° 50.35' N	0° 26.16' W	3789.0	CTD/RO
182	02.05.03	06:20	08:21	75° 0.04' N	1° 34.76' W	3745.0	CTD/RO, OP
183	02.05.03	10:32	15:17	74° 50.12' N	2° 30.46' W	3715.0	MOR
184	02.05.03	17:12	20:29	75° 0.01' N	2° 13.01' W	3656.0	CTD/RO, BO, NN
185	02.05.03	21:38	23:42	75° 0.03' N	2° 50.94' W	3709.0	CTD/RO
186	03.05.03	01:05	03:08	75° 0.04' N	3° 30.28' W	3682.0	CTD/RO
187	03.05.03	04:03	07:45	75° 5.13' N	3° 27.43' W	3685.0	MOR
188	03.05.03	10:37	14:14	74° 54.98' N	4° 37.96' W	3631.0	MOR

Station	Date	Time (UTC)		Position Lat	Position Lon	Depth [m]	Gear Abbreviation
		Start	End				
189	03.05.03	15:26	01:00	75° 0.03' N	4° 8.23' W	3662.0	MN
190	04.05.03	02:15	04:15	74° 59.95' N	4° 47.14' W	3628.0	CTD/RO
191	04.05.03	05:26	08:43	75° 0.02' N	5° 25.03' W	3590.0	CTD/RO, OP, NN, BO
192	04.05.03	10:05	12:50	75° 0.07' N	6° 3.96' W	3543.0	CTD/RO, OP, RAD
193	04.05.03	14:16	16:21	74° 59.93' N	6° 43.04' W	3507.0	CTD/RO, OP
194	04.05.03	17:40	19:39	74° 59.93' N	7° 20.78' W	3458.0	CTD/RO
195	04.05.03	21:08	23:02	74° 59.91' N	8° 1.73' W	3410.0	CTD/RO
196	05.05.03	00:41	02:39	74° 59.97' N	8° 39.85' W	3373.0	CTD/RO
197	05.05.03	04:16	07:12	74° 59.74' N	9° 18.90' W	3308.0	CTD/RO, NN, BO
198	05.05.03	09:27	12:10	75° 0.14' N	9° 55.70' W	3228.0	CTD/RO, OP, RAD
199	05.05.03	14:58	16:53	74° 59.94' N	10° 35.26' W	3084.0	CTD/RO, OP
200	05.05.03	18:31	20:38	74° 59.89' N	11° 2.02' W	2752.0	CTD/RO
201	05.05.03	22:50	00:34	75° 0.15' N	11° 28.25' W	2333.0	CTD/RO
202	06.05.03	01:47	03:17	75° 0.05' N	11° 52.05' W	1912.0	CTD/RO
203	06.05.03	04:55	05:48	74° 57.78' N	12° 18.86' W	1489.0	CTD/RO
204	06.05.03	07:37	09:32	74° 58.70' N	12° 29.22' W	1154.0	CTD/RO, OP, NN, BO
205	06.05.03	10:06	11:26	74° 59.40' N	12° 37.75' W	878.2	CTD/RO, OP, RAD
206	06.05.03	11:57	12:30	74° 59.43' N	12° 46.60' W	573.5	CTD/RO
207	06.05.03	17:00	17:22	74° 57.28' N	13° 14.92' W	274.2	CTD/RO, OP
208	06.05.03	18:45	19:03	75° 0.25' N	13° 40.24' W	206.1	CTD/RO
209	06.05.03	21:03	22:05	75° 0.80' N	14° 18.49' W	168.2	CTD/RO
210	07.05.03	01:01	01:15	74° 59.02' N	14° 59.30' W	119.3	CTD/RO
211	07.05.03	08:23	10:04	75° 0.19' N	15° 40.05' W	201.8	CTD/RO, OP, NN, BO
212	07.05.03	13:10	14:32	74° 59.92' N	16° 19.94' W	326.3	CTD/RO, OP, EF
213	07.05.03	15:47	16:46	74° 59.87' N	16° 0.30' W	266.4	CTD/RO, OP, RAD
214	07.05.03	17:40	17:58	74° 58.98' N	15° 41.68' W	206.9	CTD/RO, OP
215	07.05.03	20:56	21:19	74° 58.25' N	15° 21.27' W	159.2	CTD/RO, OP
216	07.05.03	22:35	22:49	74° 55.29' N	14° 57.40' W	143.4	CTD/RO, OP
217	07.05.03	23:23	23:44	74° 55.66' N	14° 41.03' W	180.6	CTD/RO, OP
218	08.05.03	00:16	00:30	74° 56.21' N	14° 25.39' W	173.4	CTD/RO
219	08.05.03	01:15	01:28	74° 56.12' N	14° 7.11' W	177.1	CTD/RO, OP
220	08.05.03	02:08	02:23	74° 54.45' N	13° 51.20' W	190.6	CTD/RO, OP
221	08.05.03	03:09	03:25	74° 51.26' N	13° 37.07' W	270.0	CTD/RO, OP
222	08.05.03	04:35	05:07	74° 48.22' N	13° 13.65' W	606.8	CTD/RO, OP
223	08.05.03	05:31	07:30	74° 47.22' N	13° 10.17' W	854.5	CTD/RO, OP, NN, BO
224	08.05.03	07:59	08:45	74° 46.28' N	13° 7.98' W	1046.0	CTD/RO, OP
225	08.05.03	09:18	10:42	74° 45.31' N	13° 3.72' W	1289.0	CTD/RO, OP, RAD
226	08.05.03	11:59	12:56	74° 46.71' N	12° 49.14' W	1522.0	CTD/RO, OP
227	08.05.03	13:57	18:26	74° 43.34' N	12° 41.52' W	1915.0	CTD/RO, OP
228	08.05.03	19:42	21:07	74° 39.68' N	12° 28.89' W	2316.0	CTD/RO, OP
229	08.05.03	22:09	23:38	74° 37.62' N	12° 12.51' W	2582.0	CTD/RO, OP
230	09.05.03	01:05	02:43	74° 35.03' N	11° 53.46' W	2852.0	CTD/RO, OP
231	09.05.03	04:26	06:15	74° 30.00' N	11° 23.64' W	3073.0	CTD/RO, OP
232	09.05.03	07:59	09:48	74° 23.70' N	10° 51.72' W	3132.0	CTD/RO, OP

CTD probe
RO = Rosette water sampler
OP = Optics Package: Multi Sensor Data Logger (mit CTD)
NN = Nansen net MN = Multiple net
BO = Bongo net
XBT = Expendable bathythermograph
RAD = Seawifs Profiling Multi Wavelength Radiometer
MOR = Mooring

2.11 Participants

Name	Institute
Alheit, Ruth	AWI
Allison, David Ben	SIO
Babst, Ulrike	AWI
Behrens, Melanie	AWI
Brauer, Irene	SBG
Breitenbach, Sebastian	AWI
Budéus, Gereon	AWI
Falck, Eva	AWI
Gerull, Linda	AWI
Hartmann, Carmen	AWI
Kaczmarek, Slawomir	IOPAS
Kattner, Gerhard	AWI
Knuth, Edmund	DWD
Köhler, Hayo	IBM
Kolar, Ingrid	AWI
Kolk, Annette	BIA
Lannig, Gisela	AWI
Meon, Benedikt	AWI
Metzger, Rebecca	AWI
Otto, Juliane	AWI
Plugge, Rainer	AWI
Ronski, Stephanie	AWI
Schwarz, Jill Nicola	AWI
Stöckert-Stüve, Axel	AWI
Stramska, Malgorzata	USC
Stürcken, Marthi	AWI

2.12 Participating Institutions

AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung Columbusstrasse 27568 Bremerhaven, Germany
BIA	Berufsgenossenschaftliches Institut für Arbeitssicherheit Alte Heerstr. 111 53757 St. Augustin, Germany
DWD	Deutscher Wetterdienst Bernhard-Nocht-Straße 20359 Hamburg, Germany
IBM	Institut für Biogeochemie und Meereskunde Universität Hamburg Bundesstraße 55 20146 Hamburg
IOPAS	Institute of Oceanology Polish Academy of Sciences Powstancow Warszawy 55 P.O. Box 68 81-712 Sopot, Poland
SBG	See-Berufsgenossenschaft Reimerstwiete 2 20457 Hamburg, Germany
SIO	Marine Physical Laboratory Scripps Institute of Oceanography La Jolla, CA 92093 – 0238, USA
USC	University of Southern California Mancock Institute for Marine Studies Los Angeles, CA 90089 – 0371, USA

2.13 Ship's Crew ARK XIX/2

Pahl, Uwe	Master
Schwarze, Stefan	1. Offc.
Schulz, Volker	Ch.Eng.
Fallei, Holger	2. Offc.
Hartung, René	2. Offc.
Szepanski, Nico	2. Offc.
Kohlberg, Eberhard	Doctor
Hecht, Andreas	R.Offc.
Erreth Monostori, G.	1. Eng.
Richter, Frank	2. Eng.
Simon, Wolfgang	2. Eng.
Baier, Ulrich	FielaxElo
Dimmler, Werner	FielaxElo
Fröb, Martin	FielaxElo
Holtz, Hartmut	ElecTech.
Piskorzynski, Andreas	FielaxElo
Clasen, Burkhard	Boatsw.
Neisner, Winfried	Carpenter
Burzan, Gerd-Ekkeh.	A.B.
Guse, Hartmut	A.B.
Kreis, Reinhard	A.B.
Moser, Siegfried	A.B.
Schmidt, Uwe	A.B.
Schröder, Norbert	A.B.
Schultz, Ottomar	A.B.
Beth, Detlef	Storek.
Arias Iglesias, Enr.	Mot-man
Dinse, Horst	Mot-man
Fritz, Günter	Mot-man
Krösche, Eckard	Mot-man
Fischer, Matthias	Cook
Martens, Michael	Cooksmate
Tupy, Mario	Cooksmate
Dinse, Petra	1. Stwdess
Schöndorfer, Ottilie	Stwdess/Kr
Deuß, Stefanie	2. Stwdess
Schmidt, Maria	2. Stwdess
Streit, Christina	2. Stwdess
Tu, Jian-Min	2. Steward
Wu, Chi Lung	2. Steward
Yu, Chung Leung	Laundrym.
Niehusen, Arne	Trainee/D
Scholl, Christoph	Trainee/D