Årsbok Yearbook 2007

Polarforskningssekretariatet

Swedish Polar Research Secretariat

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Omslag ***Cover***
Isbrytaren Oden anlöpte Antarktis för första gången någonsin under 2007, efter många framgångsrika expeditioner i Arktis.

During 2007, the icebreaker Oden made its first ever voyage to Antarctica, following many successful expeditions in the Arctic.

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Glaciären Eqalorutsit kangigdlît sermiat kalvar längst in i Bredefjord, även kallad Nordre Sermilik, på södra Grönland.

The Eqalorutsit Kangigdlît Sermiat glacier calving in the inner reaches of Bredefjord, also known as Nordre Sermilik, on southern Greenland.

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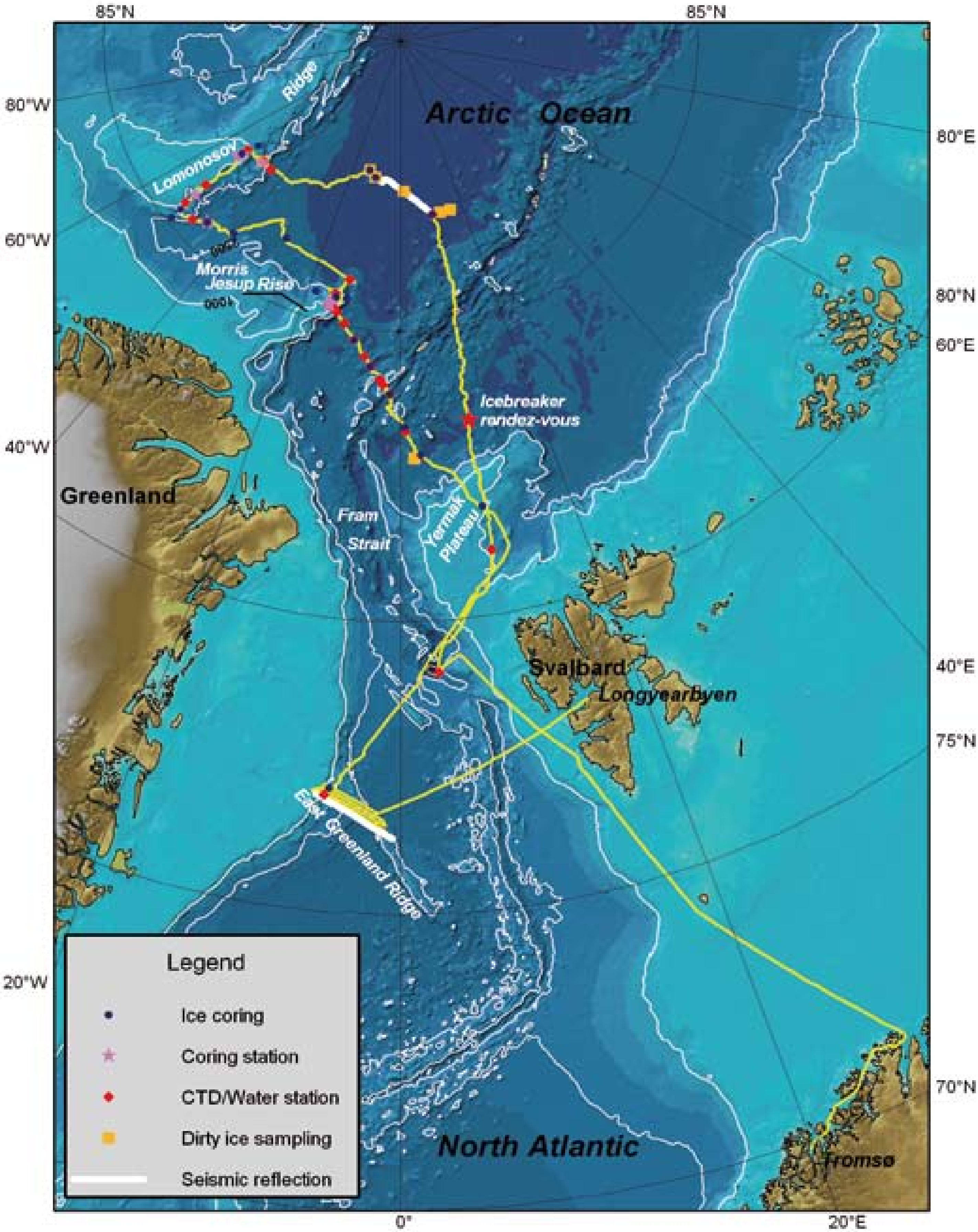
LOMROG 2007

Forskarrapporter Cruise Reports



LOMROG expedition route and scientific station work.

Lomonosov Ridge off Greenland (LOMROG) 2007: Chemical and physical oceanography

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The oceanographic component of LOMROG focuses on constraining and understanding the pathways of the Atlantic water and deep water across the Lomonosov Ridge, between the Eurasian Basin and Canadian Basin and through the western Fram Strait. A deep water pathway may exist between the Lomonosov Ridge and the Northern Greenland shelf, and thus knowledge of the shape of the seafloor in this area is also of interest for the oceanography programme. The LOMROG oceanography programme is an extension of the 2005 scientific programme conducted during the Healy-Oden Trans-Arctic expedition (HOTRAX) in 2005 when oceanographic station work was carried out from the icebreaker Oden and multibeam mapping from USCGC Healy. The data from HOTRAX showed that water overflow from the Makarov Basin (part of the Canadian Basin) to the Amundsen Basin (part of the Eurasian Basin) takes place across a 1 870 m deep sill in the central Lomonosov Ridge at about 88°25'N, 150°E (Björk et al. 2007). This water appears to follow the Lomonosov Ridge slope southwards towards Greenland but uncertainty remains in regard of whether it can be traced on the southernmost tip of the ridge and how the circulation continues from this point and onwards.

Data acquisition

Conductivity Temperature Depth (CTD) and water sampling were carried out at 26 stations covering parts of the western Eurasian Basin and one station at the East Greenland continental margin. Water was collected using a 24-bottle rosette sampler equipped with 7.5 l Niskin type bottles and a CTD (Sea Bird 911+) (Fig. 1). When brought back onboard the rosette was moved into a heated double container as quickly as possible to avoid freezing the samples. Water samples were immediately drawn for the individual parameters to be determined in the following order: CFCs, oxygen, dissolved inorganic carbon/pH/total alkalinity, nutrients, oxygen-18, and salinity. Number of samples analysed for the different constituents are given in Table 1.

Shipboard processing

The CTD data were processed through the standard Sea-Bird software routines (data conversion, cell thermal mass, filter, loop edit, derive and bin average). The final data is averaged in 1 dbar bins. Salinities were also determined in each Niskin bottle using an Autosal lab-salinometer. The temperature in the clean room inside the laboratory on the foredeck fluctuated significantly and therefore conditions were not ideal for the salinity analyses, but were nevertheless manageable. The final bottle salinity data should be of good quality with an accuracy of ±0.001 psu. The bottle salinities were then compared with the CTD bottle file data in order to check the accuracy of the CTD system. The comparison with bottle data showed an offset of about -0.0044 psu between the CTD and Autosal salinities, inferring that the CTD sensor values were too low. The final CTD data were corrected by determining an average salinity offset using bottles with salinity > 34.8 psu and excluding outliers outside 1 SDA. One sample was then identified (Station 20, 4 000 dbar) as having identical offset as the average offset. The Autosal conductivity for this sample was determined for the same temperature and pressure when the bottle was tripped (P=4 000 dbar, T=-0.6708°C). The Autosal conductivity divided by the CTD conductivity then gives a slope correction of 1.000119, which has been used

Figure 1
The CTD/rosette sampler on its way back from the water. Photo: Sofia Rickberg.

Figure 2
Sara Jutterström collecting water for the determination of DIC. Photo: Leif Anderson.

to post-process the data according to Sea-Bird recommendations.

Water for chemical analysis was drawn from water samplers directly after the rosette was brought on board and analysed within hours of sampling. The precisions given below were computed as standard deviations of duplicate analyses. Samples for CFCs were drawn from the bottles on the rosette with glass syringes, which were kept under cold water until analysis (within a few hours). They were measured by purge-and-trap extraction and pre-concentration, gas chromatographic separation on a capillary column, and electron capture detection calibrated against a standard gas mixture. The precision was in the order of 1% and the accuracy was about 0.02 pmol/kg. Oxygen was determined using automatic Winkler titration system, precision ~1 µmol/kg. Total dissolved inorganic carbon (DIC) was determined by a coulometric titration method having a precision of ~1 µmol/kg, with the accuracy set by calibration against certified reference materials (CRM), supplied by A. Dickson, Scripps Institution of Oceanography (USA). Total alkalinity (TA) was determined by potentiometric titration, precision ~1 µmol/kg, (Haraldsson et al. 1997), with the accuracy set in the same way as for DIC. The determination of pH was performed by the use of a diode-array spectrophotometer using a sulphonephtalein dye, m-cresol purple, as indicator (Clayton and Byrne 1993, Lee and Millero 1995), and measured in a 1 cm flowcell thermostated to 15°C (pH15). The precision and accuracy for the pH15 measurements were ±0.0005 and ±0.002 pH units, respectively. pH in situ was calculated from TA, pH15 and in situ temperature by using the CO_2-system program by Lewis and Wallace (1998). For these calculations the carbon dioxide constants of Roy et al. (1993 and 1994) were applied, and the pH was on the total hydrogen ion scale. The nutrients (phosphate, nitrate, and silicate) were determined using a SMARTCHEM auto-analyser applying standard analytical protocol giving a precision near 1% at full scale.

Preliminary results

The observations at the Amundsen Basin slope of the Lomonosov Ridge (Stations 4, 9 and 10) show a clear signal of Canadian Basin Deep Water (CBDW) at around 2 000 m with similar characteristics to a station (Station 41) in the vicinity of the 1 870 m deep channel in the central Lomonosov Ridge at about 88°25'N, 150°E found during the Beringia/HOTRAX 2005 expedition (Björk et al. 2007) (see also Figure 3 for some selected station data). A vertically broad CBDW signal was also clearly visible at the flanks of the Morris Jesup Plateau (Stations 12, 17, 18 and 19). A more vertically narrow and weaker signal was observed over the western Amundsen Basin (Stations 3 and 21–25). The observations

Table 1. Station numbers with positions and bottom depth, and number of data per individual constituent and station.

Station	Latitude	Longitude	Bottom depth	CFC	Oxygen	Mercury	DIC	pH	TA	Nutrients	O-18	Salinity
1	79.121	3.411	5160	3	3	3	0	3	0	0	0	0
2	81.113	9.854	1573	15	15	10	13	15	14	15	0	15
3	86.968	10.168	4338	23	23	12	22	23	23	23	10	23
4	86.883	-44.628	3444	23	23	12	23	23	23	23	10	23
5	86.899	-48.236	1807	18	18	6	18	4	18	18	10	18
6	86.816	-53.826	967	16	16	4	16	16	16	16	10	16
7	85.892	-52.919	749	21	21	8	21	21	21	21	15	18
8	85.432	-52.383	1189	22	22	8	21	22	22	22	12	19
9	85.345	-48.708	2433	19	19	12	19	19	19	19	8	19
10	85.493	-46.189	3005	0	0	10			14	20	0	
11	85.803	-11.723	3985	24	24	12	24	24	24	24	12	23
12	85.519	-14.178	3061	21	21	12	21	21	21		12	21
13	85.479	-13.865	2113	23	23	8	23	23	23	23	?	23
14	85.410	-14.303	1340	19	19	0	19	19	19	19	10	19
15	85.294	-14.936	1004	17	17	0	17	17	17	17	10	17
16	85.269	-13.875	1074	20	20	10	20	20	20	19	12	19
17	85.212	-13.173	2473	22	22	12	22	22	22	22	12	20
18	85.211	-12.997	3360	23	24	12	24	24	24	24	12	21
19	85.041	-11.106	3890	24	24	0	24	24	24		12	24
20	84.790	-8.703	3989	24	24	0	24	23	24		11	24
21	84.531	-6.399	4081	24	24	12	24	24	24	24	12	24
22	84.369	-5.196	3915	24	24	0	24	24	23	24	12	24
23	84.154	-3.431	3003	22	22	0	22	22	22	22	12	22
24	84.074	-2.929	2616	21	21	11	21	21	21	21	12	21
25	83.911	-1.682	3139	23	24	0	24	24	24	24	12	24
26	83.273	0.651	3742			8						

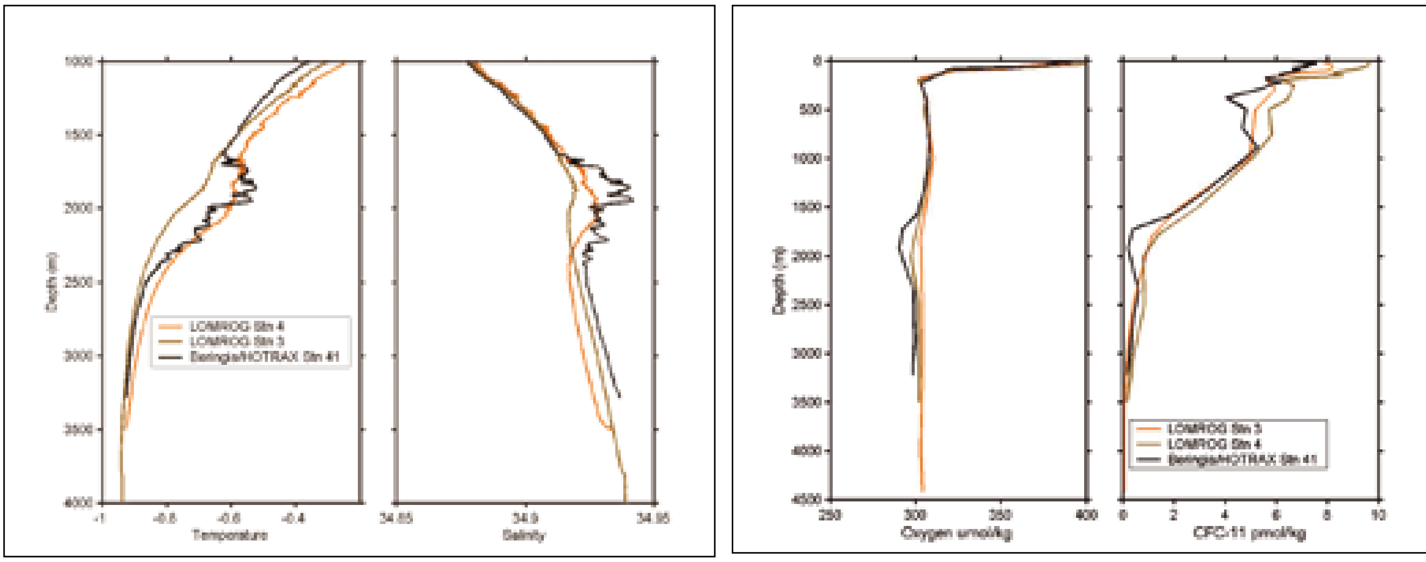

Figure 3
Temperature and salinity data showing the structure of the CBDW signal seen as a temperature and salinity maximum at around 2 000 m depth. The CBDW water is also less ventilated ("older") which is seen in the oxygen and CFC-11 signals. The Beringia/HOTRAX station 41 is from the central Lomonosov Ridge, LOMROG Station 4 is further towards Greenland at the Amundsen Basin flank of the ridge, and LOMROG Station 3 is from the central Amundsen Basin.

during LOMROG infer that the major inflow of CBDW to the Amundsen Basin indeed occurs at the central Lomonosov Ridge channel and that the flow continues along the slope of the ridge towards Greenland. The further circulation follows the Greenland continental slope towards the southeast to the Morris Jesup Plateau where eventually some of the flow leaves the continental slope, becomes interleaved, and can be identified as a weak salinity maximum over the central Amundsen Basin.

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LOMROG: Kemisk och fysisk oceanografi

Målsättningen med det oceanografiska projektet under expeditionen Lomonosov Ridge off Greenland (LOMROG) var att samla information för att dels bättre förstå hur olika vattenmassor strömmar över Lomonosovryggen och efter Grönlands nordostkust mot de Nordiska haven, dels upprepa en del av de undersökningar som gjordes under expeditionen Arctic Ocean 1991. Motiveringen är att studera hur vattnen i den Arktiska oceanen samverkar med Nordatlanten i en tid av förändrat klimat, och om det finns förändringar som redan kan observeras norr om Grönland. För dessa undersökningar samlades djupprofiler från 26 stationer där vattenprover togs för bestämning av flera olika kemiska parametrar ombord på Oden. De första resultaten visar en tydlig signal av vatten från den Kanadensiska bassängen kring 2 000 m vattendjup efter Lomonosovryggen i den Eurasiska bassängen och på flanken av Morris Jesup-platån. Längs sektionen sydöst om Morris Jesup-platån är det tydligt hur signalen av antropogen koldioxid har växt till sig i de översta 2 000 metrarna. Denna signal är också tydlig i kemiska parametrar som uttrycker hur länge sedan ett vatten var i kontakt med atmosfären, dvs. var vid ytan.

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Lomonosov Ridge off Greenland (LOMROG) 2007: Accumulation of mercury in the Arctic Ocean

Emissions of mercury

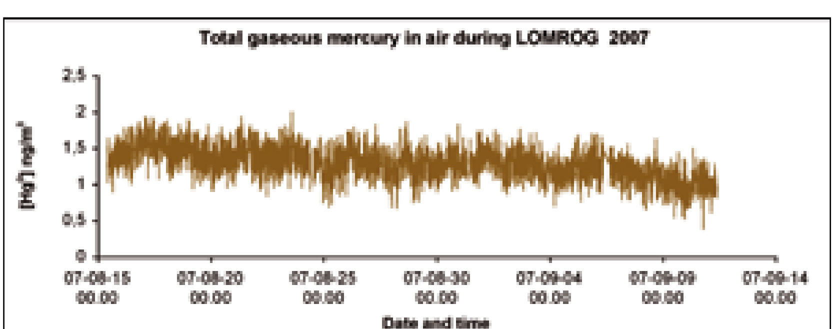
As a consequence of long-range transport of manmade emissions into the atmosphere, the Polar Regions are nowadays contaminated with highly neurotoxic mercury (Hg). About 6 000 tonnes of Hg are present in the atmosphere today, mainly originating from anthropogenic emissions in the industrialized part of the world. Mercury is one of the most dangerous environmental pollutants, and since it is an element, it cannot be destroyed. Mercury poisoning of the planet could best be reduced by curbing pollution from power stations, since coal-fired power stations and waste incinerators account for around 70 percent of new, quantified manmade mercury emissions to the atmosphere (UNEP 2002).

Mercury is biomagnified in marine wildlife

The most toxic form of mercury is monomethylmercury (MMHg), which is formed in aquatic environments after deposition of inorganic mercury. MMHg is bioaccumulated in fish, and fish contaminated with MMHg is hazardous to eat because MMHg passes the blood brain barrier and the placenta in pregnant women, and can therefore be dangerous to the foetus.

The level of Hg found in marine mammals in the Canadian Arctic exceeds guideline limits for Hg contamination of food for human consumption. Moreover, Hg levels in Arctic ringed seals and beluga whales have increased by a factor of up to four over last the 25 years and the levels recorded in indigenous people living in the Arctic exceed those in people from more temperate, industrial regions. In a study on 7-year-old children in the Faeroe Islands, it has been shown that prenatal methyl mercury exposure may lead to neuropsychological dysfunctions, such as problems in language acquisition, attention and memory deficit (Grandjean 1997). According to exposure data published by the U.S. Center for Disease Control and Prevention, the number of babies at risk in the U.S. could be as high as 300,000. On a global scale, that number can be increased to several million (UNEP 2002).

Figure 1
Total Gaseous Mercury (TGM) measured in air at 20 m above sea level during the LOMROG expedition.



Long-range transport and chemical transformation contributes to deposition of mercury in the Arctic

Atmospheric deposition of Hg in the Arctic is post-industrially driven, and high Hg concentrations in the upper layer of polar lake sediments have been found (Steffen et al. 2007 and references therein). Ice core samples confirm these results, and the same trends are also observable in, for example, peat from southern Greenland.

Enhanced mercury deposition is observed in the arctic environment, and one important factor influencing the deposition of the species is so-called atmospheric mercury depletion events (AMDE). These events occur during the polar spring and a substantial amount of the global atmospheric Hg pool, that is to say, approximately 300 tonnes per year, is deposited in the arctic environment (Ariya et al. 2004, Skov et al. 2004, Sommar et al. 2007). In addition to atmospheric deposition of Hg, the species may also enter the polar basin via oceanic currents and river input. However, while land based measurements of Hg species are represented in literature, information is lacking on the relative importance of various sources of mercury to the polar basin today. Our work contributes to an extensive investigation on water and air masses, aiming at an assessment of mercury sources and sinks in the Polar Basin. The measurements have been conducted under the umbrella of the LOMROG and Beringia expeditions, both arranged by the Swedish Polar Research Secretariat in 2007 and 2005 respectively.

Mercury sampling in Arctic seawater and air

To estimate the input and accumulation of mercury in Arctic marine waters, about 200 samples for determination of total mercury (Hgtot) and MMHg were taken at some 20 stations along the LOMROG 2007 expedition route, and around 500 samples were taken for the same species at 48 stations during the expedition Beringia 2005. Continuous measurements of total gaseous mercury (TGM) in air were also conducted during both expeditions using a Tekran 2537A mercury vapour detector, and a portable mercury analyser i.e. LUMEX Mercury Analyzer RA-915+. Figure 1 presents data on concentrations of elemental mercury in air recorded during the LOMROG expedition over a period of 22 days, between 15 August and 6 September 2007. The average concentration of TGM during this period was 1.3 ± 0.2 ng/m^3. The data will be further analysed with respect to a number of ambient parameters, such as wind conditions and sea ice coverage.

The mercury sampling in water was designed as profile measurements at various latitudinal sites at the LOMROG and Beringia CTD water stations sites respectively, and will be analysed in combination with data on movements of the water masses. In addition, a transect for sampling of surface water using the water sample system in the boat were performed when crossing the Greenland Sea from 76°44'N and 1°22'E to 78°06'N and 13°24'E off the west coast of Svalbard. For each sample, 125 ml of seawater was collected in acid washed Teflon bottles and these are currently being analysed for Hgtot by purge and trap technique as described in Gårdfeldt (2002). Determination of MMHg content in the samples is conducted after derivatisation by an ethylating agent using the gas chromatography CVAFS technique as described in Lee et al. (1994).

During the Beringia 2005 expedition continuous measurements of dissolved gaseous mercury (DGM) were performed using a new method first described in Andersson et al. (2007a). Part of the data from these measurements is presented in Figure 2, and is thoroughly described in Andersson et al. (2007b and 2007c).

Multiphase investigations combining oceanography and mercury speciation, as performed during the LOMROG 2007 and Beringia 2005 expeditions, comprise a unique series of Hg sampling. The data archived will help to assess the Hg sources, the accumulation and the long-term fate of mercury in the polar ecosystem. Preliminary results from our measurements show that the enhanced deposition and river input of mercury species, in combination with restricted evasion at northern latitudes compared to more southern latitudes, result in an accumulation of mercury in the polar water body. For example, the concentration of dissolved gaseous mercury is up to ten times higher in the Arctic Basin compared to the North Atlantic Ocean.

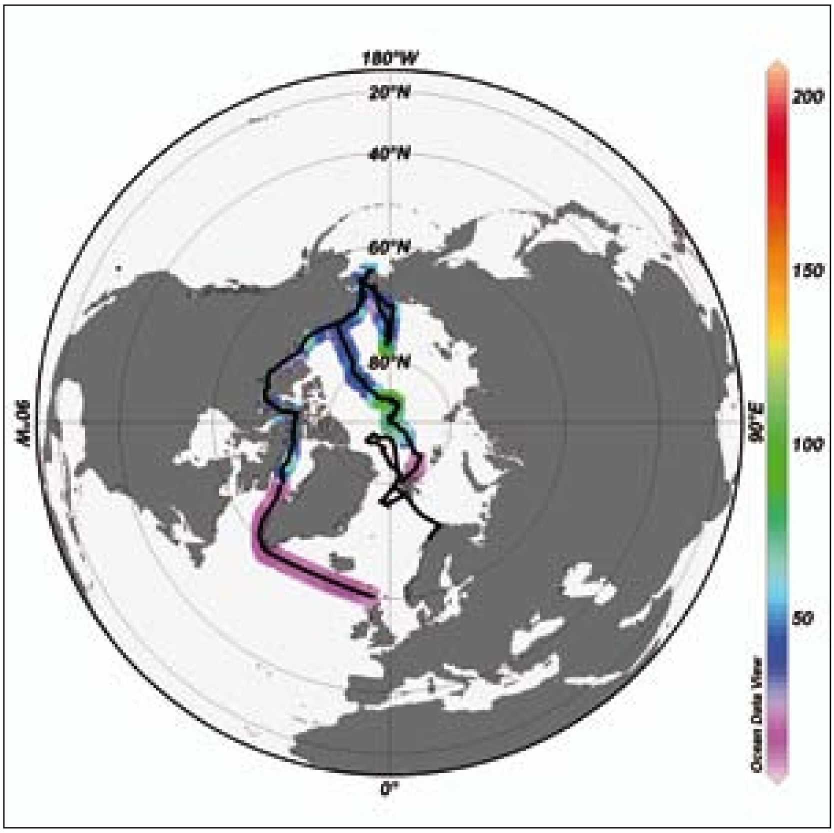


Figure 2
Continuous measurements of total gaseous mercury in air (black line) and dissolved gaseous mercury in surface water (line in colours) during the expeditions Beringia 2005 and LOMROG 2007. Schlitzer, R., Ocean Data View, http://odv.awi-bremer-haven.de, 2004.

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LOMROG: Ackumulationen av kvicksilver i Arktiska oceanen

Som en följd av förbränning av kol och olja i världen sprids kvicksilver genom luften och årligen deponeras 100-tals ton av metallen i Arktis. Organiskt kvicksilver, som kan bildas efter deposition av luftburet kvicksilver, är mycket giftigt och bioackumuleras i fisk och däggdjur. Under de två expeditionerna Beringia 2005 och LOMROG 2007 har vi gjort mätningar på luft, vatten, snö och is som syftar till att uppskatta ackumulationen av kvicksilver i Arktis. Våra mätningar visar att halterna av vissa former av kvicksilver i Arktiska oceanen är kraftigt förhöjda jämfört med andra havsområden. Halten av löst gasformigt kvicksilver i ytvatten är t.ex. upp till 10 gånger så höga i den Arktiska bassängen som i norra Atlanten.

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Lomonosov Ridge off Greenland (LOMROG) 2007: Coring and high-resolution geophysical mapping

Introduction and background

The Arctic Ocean north of Greenland is virtually unexplored due to predominantly heavy sea ice conditions that have made the area by and large inaccessible. Icebreakers have previously never attempted to reach the southern tip of the submarine Lomonosov Ridge that extends towards the northern Greenland continental margin. Among the scientific ice drift stations, only the GreenICE camp in 2004 has investigated a fragment of the southwesternmost part of the ridge (Kristoffersen and Mikkelsen 2006). This ice-infested area of the Arctic Ocean was the focus for the Lomonosov Ridge off Greenland (LOMROG) 2007 expedition as it is probable that it holds answers to key questions regarding ocean circulation and glacial history, such as the question whether immense Antarctic style ice shelves existed in the Arctic Ocean during past glacial periods. Previous expeditions to the Lomonosov Ridge with Swedish icebreaker *Oden* in 1996 and the US nuclear submarine *Hawkbill* in 1999 demonstrated the occurrence of glacial ice grounding down to 1 000 m present water depth at about 87°N (Siberian side) on the ridge crest (Jakobsson 1999, Polyak et al. 2001). If this ice grounding event resulted from a much debated (e.g. Mercer 1970), but supposedly coherent and large floating ice shelf, the Lomonosov Ridge north of Greenland should also be scoured. To test the hypothesis of a huge Arctic Ocean ice shelf, LOMROG mapped the Lomonosov Ridge and Morris Jesup Rise north of Greenland as well as the Yermak Plateau north of Svalbard using the new multibeam bathymetric sonar and chirp subbottom profiling system installed on the Oden during the spring of 2007 (Fig. 1). In addition, sediment cores were taken from the surveyed areas for palaeoceanographic studies, and sediment samples were collected from "dirty" patches of drifting ice floes for modern provenance studies. With this material, the history of the Arctic Ocean circulation and sea ice cover will be addressed, such scientific questions being of particular relevance in the context of the present trend of diminishing Arctic Ocean sea ice cover, where September in the year of 2007 showed the aerially smallest extent ever measured over the last 28 years (National Snow and Ice data Center: http://nsidc.org).

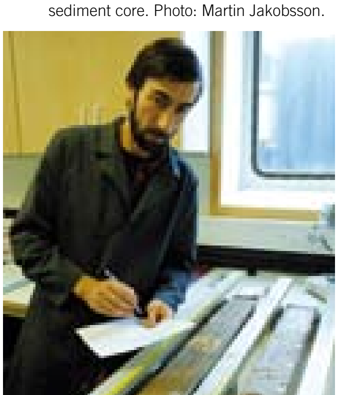
However, it should be noted that in the LOMROG operating area north of Greenland severe sea ice conditions were encountered with 10/10 ice cover and sometimes ~4 m thick multiyear floes.

The second major component of the LOMROG expedition consisted of the Danish Continental Shelf Project (Marcussen et al. this volume). This project collected seismic reflection profiles and bathymetry in order to acquire the base data needed to eventually put forward an Article 76 of United Nations Convention of the Law of the Sea (UNCLOS) claim for a new legal definition of Denmark's continental margin north of Greenland. Furthermore, LOMROG included a number of scientific subprojects. These comprised studies of the return flow of Atlantic water and deep water exchange between the Eurasian and Amerasian Arctic Ocean basins (Anderson et al. this volume), the role of sea ice in the transport of CO_2 from the atmosphere to the ocean (Rysgaard et al. this volume), distribution of mercury in the atmosphere and ocean (Gårdfeldt et al. this volume), and the Arctic Ocean gravity field (Marcussen et al. this volume).

The LOMROG expedition constitutes a project in the Arctic Palaeoclimate and its Extremes (APEX) research network programme

Figure 1
Overview of the coring operations on the Oden's aft deck. The up to 12 m long and 1.5-ton heavy piston corer was launched using a cradle gliding on a rail mounted on the aft deck. This new launching system was installed just prior to the expedition in Landskrona while Oden was in dry dock. It proved to be excellent and significantly reduced the coring station times compared to previous expeditions. Photo: Martin Jakobsson.

Figure 2
Leonid Polyak describing a section of a sediment core. Photo: Martin Jakobsson.



endorsed by the International Arctic Science Committee (IASC) and the ICSU/WMO Joint Committee for the International Polar Year 2007–2008 (IPY).

LOMROG ship based work and preliminary results

Despite severe sea ice conditions Oden, supported by the newest Russian nuclear icebreaker 50 let Pobedy, managed to reach the previously unexplored southernmost tip of the Lomonosov Ridge north of Greenland to conduct scientific work (See map p. 126 and Fig. 1). Large pressure ridges and thick multiyear sea ice prevented mapping with the multibeam and subbottom profiler along straight predefined tracks. The surveys were instead dictated by the few existing crack systems in the sea ice and openings in the large pressure ridges that allowed 50 let Pobedy and Oden to break through. Another problem for the acoustic mapping was the crushed ice in the wake of 50 let Podedy, which reduced the data quality significantly, in addition to the noise from the icebreaking. This ice slush was pressed underneath the hull of Oden and occasionally completely covered the hull-mounted multibeam and subbottom acoustic transducers. However, even though LOMROG faced certain difficulties in the sea ice over the Lomonosov Ridge, valuable geophysical data were collected. In addition, six sediment cores were retrieved from this area, both from the shallow ridge crest and the slope towards Amundsen Basin (see map p. 126). Preliminary analysis of the multibeam and subbottom data show glacial erosion at water depths shallower than approximately 800 m on the Lomonosov Ridge and the sediment cores retrieved from the glacially scoured sea floor contained diamicton. A first hand analysis seems to support the hypothesis of glacial ice grounding on the shallow ridge crest.

The Lomonosov Ridge programme was shortened due to damage of 50 let Pobedy's propeller blade in the hard ice conditions. The next target for LOMROG was the Morris Jesup Rise where Oden had to operate without support from the Russian nuclear icebreaker. The sea ice cover was here 10/10 as in the Lomonosov Ridge area, although large pressure ridges were less abundant. A completely new multibeam survey technique was invented that proved very successful in extreme ice conditions. This technique, named "pirouette surveying", involved Oden stopping and turning around in a half circle while acquiring multibeam data whenever an open to semi-open lead in the pack ice was encountered (Fig. 4). The idea was to cover a 360° sector around the ship equal to the multibeam swath width, which was commonly between 3–4 times the water depths, although sometimes we achieved a swath up to 5 times the water depth. Occasionally the ship was rotated 360° to increase the resolution of the mapped area underneath the ship. After one "pirouette" was completed, Oden broke ice using its full capacity to the end of the multibeam swath coverage, where a new pirouette was carried out. The Morris Jesup Rise's northern slope and shallow crest was successfully mapped using this technique. The data reveal large iceberg scours down to a water depth of approximately 1 050 m, so far the largest and deepest iceberg scours mapped in the Arctic Ocean (Fig. 2). The coring programme on the Morris Jesup Rise targeted undisturbed sediment sections for palaeoceanographic studies as well as the largest ice scour ever mapped. The purpose of coring the ice

Figure 3
The new Russian nuclear icebreaker 50 let Podedy supporting Oden in the areas of the Arctic Ocean north of Greenland. Photo: Martin Jakobsson.

scour was to investigate the age of the ice-grounding event that caused it. This can be achieved by dating the sediments that accumulated since the scouring event. The newly installed chirp sonar profiler provided the critical data in order to precisely locate optimal coring sites. Altogether, four cores were retrieved from the Morris Jesup Rise. All sediment cores were directly logged on board Oden with a Multi Sensor Track Core Logger (MSCL) measuring sediment bulk density, p-wave velocity and magnetic susceptibility. After core logging, the cores were split and described.

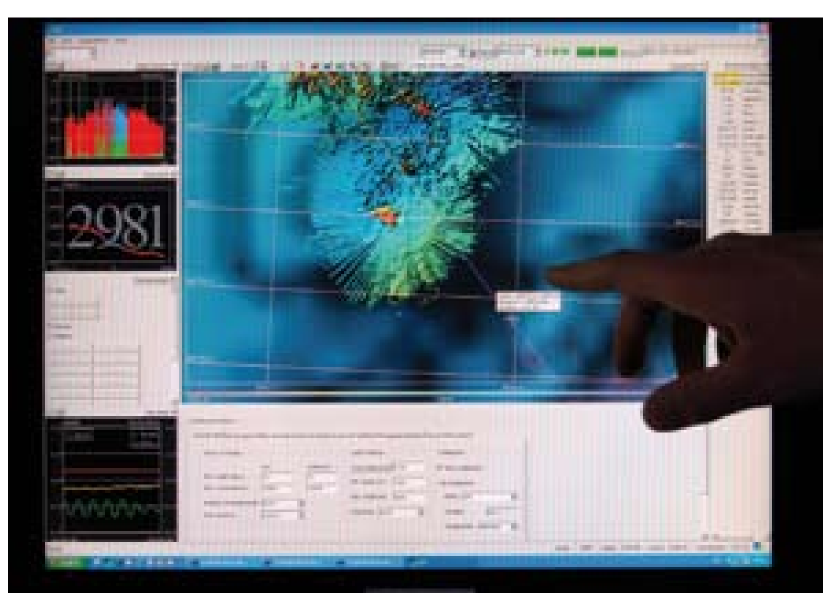
After completion of the scientific programme on the Morris Jesup Rise, an oceanographic section across the western Fram Strait was conducted. Conductivity Temperature Depth (CTD) measurements and water sampling were carried out along this section at regularly spaced stations (see map p. 126 and Anderson et al. this volume). The marine geological/geophysical programme was working in close cooperation with the oceanographic component, for example, the CTD data are used to calculate sound speed profiles of the water column that, in turn, are used to calibrate the multibeam sonar in order to get "true" depths of the sea floor.

In 2005, the US icebreaker Healy crossed the Yermak Plateau during the Healy-Oden Trans Arctic Expedition (HOTRAX) and the Beringia expedition and mapped portions of the shallow crest with their Seabeam 2112 multibeam sonar (Darby et al. 2005, Jakobsson et al. 2005). On the way to the next LOMROG major survey area, the East Greenland Ridge, Oden's route was carefully offset to the Healy 2005 track on the Yermak Plateau in order to extend the previous multibeam survey. The new geophysical mapping data collected with Oden's EM120 multibeam and SBP120 chirp sonar profiler revealed details that were previously not seen and further analysis may elucidate the behaviour of the Barents and Kara Sea ice sheet during previous glaciations.

The last area to be surveyed during the LOMROG expedition was the East Greenland Ridge (see map p. 126) where a large part of the geophysical survey was carried out in open sea with only some occasional scattered ice floes. Only in the western part of the surveyed area close to the shelf break, was icebreaking required in 7 to 9/10 sea ice cover. The East Greenland Ridge survey was entirely a part of the Danish Continental Shelf Project and consequently those results are further reported by Marcussen et al. (this volume).

The LOMROG expedition, which started 11 August in Tromsö, Norway, was completed on 16 September in Longyearbyen, Svalbard. The multibeam sonar and subbottom profiler were operated continuously along the

Figure 4
Photo showing the data acquisition window of Oden's EM120 multibeam system. The example shows how bathymetric data was collected in a 360° sector around the ship, referred to as "pirouette surveying" (see text for explanation). This way of carrying out multibeam mapping worked well in hard ice conditions where the heavy ice breaking otherwise significantly disturbed the data acquisition. Photo: Martin Jakobsson.



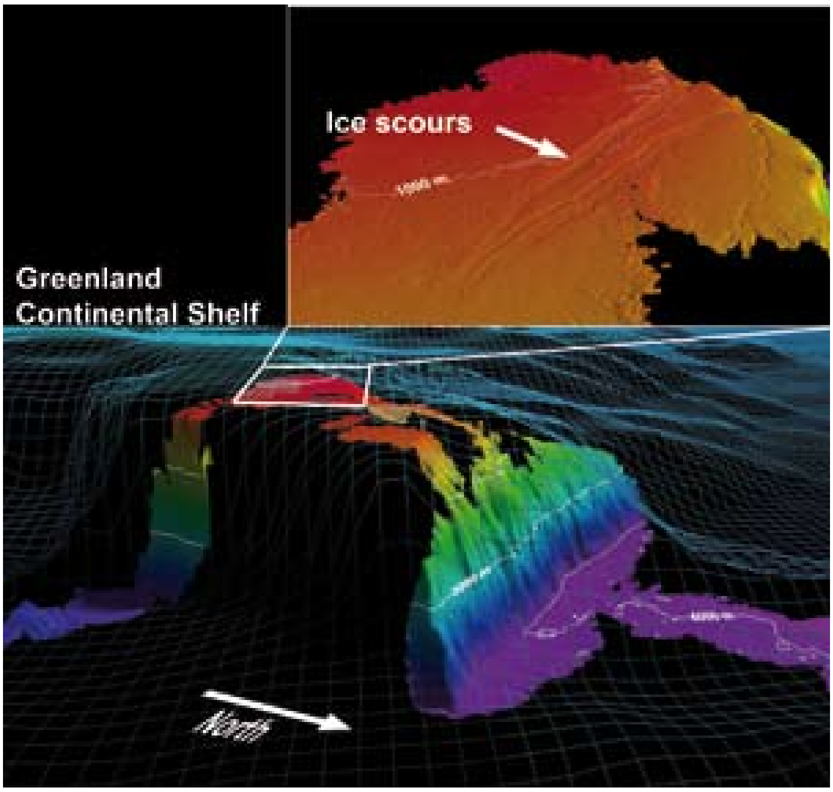


Figure 5
3D-view of the multibeam mapped Morris Jesup Rise (see Fig. 1 for general location). The International Bathymetric Chart of the Arctic Ocean (IBCAO) grid model is shown (blue grid) as a comparison to the new detailed multibeam bathymetry.

approximately 6 900 km long expedition track. Two multibeam operators were always on watch 24 hours 7 days a week and the Swedish and Danish teams collaborated by assigning personnel to this task from both groups. The data quality vary largely with the sea ice conditions; although we learned that high quality data can be collected even during the hardest possible conditions using the "pirouette technique". LOMROG was the first icebreaker expedition to reach the southern Lomonosov Ridge north of Greenland.

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LOMROG: Sedimentprovtagning och högupplöst geofysisk kartering

Norr om Grönland ligger Arktiska oceanens mest svårtillgängliga område. Havsisen är här mer kompakt än i de centrala delarna och stora tryckryggar tornar upp sig i islandskapet. Inget ytgående fartyg har tidigare opererat i området där den submarina Lomonosovryggens sydligaste del sträcker sig mot den Grönländska kontinentalshelfen. Detta område var målet för expeditionen Lomonosov Ridge off Greenland (LOMROG). Med hjälp av den nya ryska isbrytaren 50 let Pobedy (50 år av seger) nådde Oden Lomonosovryggens sydligaste spets som första ytgående fartyg. Syftet var att med hjälp av Oden's nya multibeam- och sedimentekolod samt sedimentprovtagning undersöka Arktiska oceanens glaciations- och cirkulationshistoria. Bakgrunden är att tidigare fragmentariska data – insamlat från området av ubåtar och isdriftstationer – pekar på att ryggen här når grundare än tusen meter, och att dess form påminner om de centrala delarna av ryggen där spår av glacial iserosion hittats ända ned till 1 000 meters vattendjup. Detta gör området mycket intressant för frågeställningen om det någon gång under tidigare istider funnits nära 1km tjocka shelfisar i den Arktiska oceanen. De nya LOMROG-mätningarna påvisade glacialerosion ner till omkring 800 m på Lomonosovryggen norr om Grönland. Multibeam och sedimentekolodning genomfördes också på Morris Jesup-platån, som skjuter ut från den grönländska kontinentalsockeln. Här upptäcktes isbergsspår ner till mer än 1 000 m vattendjup vilket är djupare än vad som tidigare uppmätts i centrala Arktiska oceanen.

Lomonosov Ridge off Greenland (LOMROG) 2007: Danish Continental Shelf Project

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Introduction and background

The area north of Greenland is one of three potential areas off Greenland for extension of the continental shelf beyond 200 nautical miles according to the United Nations Convention on the Law of the Sea (UNCLOS), article 76 (Marcussen et al. 2004). The technical data needed for a submission to the Commission on the Limits of the Continental Shelf (CLCS) include geodetic, bathymetric, geophysical and geological data. Acquisition of the necessary data poses substantial logistical problems due to the ice conditions in the area north of Greenland.

As the Danish part of the LOMROG expedition was the first Danish ship borne activity in the Arctic Ocean ever, one of the main goals of the expedition was to test the data acquisition concepts and especially the new reflection seismic equipment on board Oden under severe ice conditions (10/10 of several meters thick multi-year sea ice under compression). It was furthermore planned to acquire as much bathymetric data as possible to support the delineation of the foot of the continental slope, to map the sediment thickness in the Amundsen Basin and to investigate the bathymetric trough between the Lomonosov Ridge and the Canada/Greenland shelf. The Canadian Continental Shelf project participated with a small bathymetric programme planned in Canadian waters. Finally, acquisition of gravity data was planned to support the mapping of the sediment thickness.

The Danish Continental Shelf Project (www.a76.dk) funded half of the costs for Oden and the full costs for the Russian nuclear icebreaker 50 let Pobedy.

Figure 1
Seismic equipment used during the LOMROG cruise. Photos: Thomas Vangkilde-Pedersen.

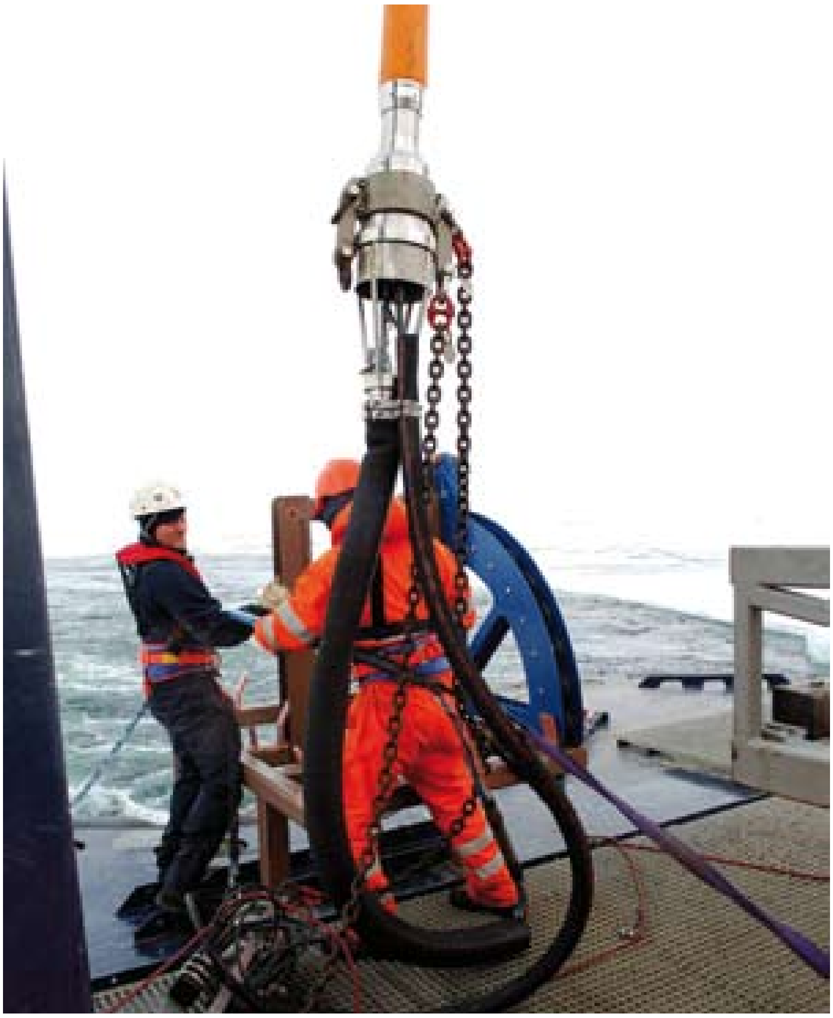

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Figure 2
Launching of the seismic equipment: Airgun cluster lower left and umbilical head above the two participants. Photo: Trine Dahl-Jensen.

Table 1	Summary of acquisition parameters
Source	**2 Sercel G and 1 Sercel GI gun**
Chamber volume	605 cu inch (250 + 250 + 105)
Pressure	200 bar (3000 psi)
Mechanical delay	16 ms
Nominal tow depth	20 m
Streamer	**Geometrics GeoEel**
Length of tow cable	43 m
Length of stretch section	50 m
No. of active sections	6 / 5 / 4 / 3
Length of active sections	300 / 250 / 200 / 150 m
No. of groups in each section	8
Total no. of groups	48 / 40 / 32 / 24
Group interval	6.25 m
No. of hydrophones in each group	8
Depth sensor	In each section
Nominal tow depth	20 m
Acquisition system	**Geometrics GeoEel controller**
Sample rate	1 ms
Low-cut filter	Out
High-cut filter	Anti-alias (=500 Hz)
Gain setting	6 dB
No. of recording channels	48 / 40 / 32 / 24
No. of auxiliary channels	4
Shot spacing	25 m
Record length	Variable between 8.5 and 11 s

Seismic data acquisition

The seismic reflection equipment used during the LOMROG cruise has been developed in co-operation with the Department of Earth Science, University of Aarhus, and is based on the experience gained by various people who have acquired reflection seismic data in the Arctic Ocean from icebreakers since 1991 (especially Yngve Kristoffersen, Art Grantz and Wilfried Jokat).

The crucial issue of seismic data acquisition in ice covered waters is to protect the seismic equipment from being damaged by sea ice while simultaneously acquiring useful data in this very noisy environment. It was therefore decided to tow both airgun and streamer at a suitable depth (approximately 20 meters below water surface), to ensure that the equipment would stay clear from the propeller wash behind the ship. However, at such a large source depth the surface ghost reflections will cause undesirable notches in the source spectrum at 30 Hz and 60 Hz.

The seismic equipment is fully containerized and consists of a winch container with three winches, a compressor container, a recording container and a storage container. A heavy duty umbilical both feeds the airguns with compressed air and connects with the seismic streamer. For smooth launch and retrieval of the equipment the winches and Oden's A-frame were used. Acquisition parameters are summarized in Table 1.

Due to the short length of the seismic streamer, velocity information from the sedimentary units is very limited. However, sediment velocities are important for the documentation of the sediment thickness of the extended continental shelf, if the 1%-sediment-thickness formula (Gardiner line) has to be applied. Therefore, sonobuoys were deployed along the seismic lines to record the seismic signals at larger offsets.

On-board processing (using ProMax software) concentrated on the evaluation of data quality, noise reduction and acquisition parameters. It showed that the noise level after processing is acceptable considering the conditions under which the data were acquired. Analysis of subsets of the seismic data indicated that a streamer with four sections instead of six sections would provide record sections with only slightly reduced data quality.

Seismic data acquisition started in the Amundsen Basin, where an approximately

130 km long profile was acquired over the course of two days. A brute stack section from onboard data processing is shown in Figure 3 (see map p. 126 for location). At the southern part of the Lomonosov Ridge area only 15 km of seismic data were acquired due to severe ice conditions. The most vulnerable part of the seismic equipment is the streamer and due to the ice conditions parts of the streamer were lost on two occasions. Finally a 165 km long seismic line supplemented by seven sonobuoys was acquired in the area where the East Greenland Ridge abuts on the North East Greenland shelf.

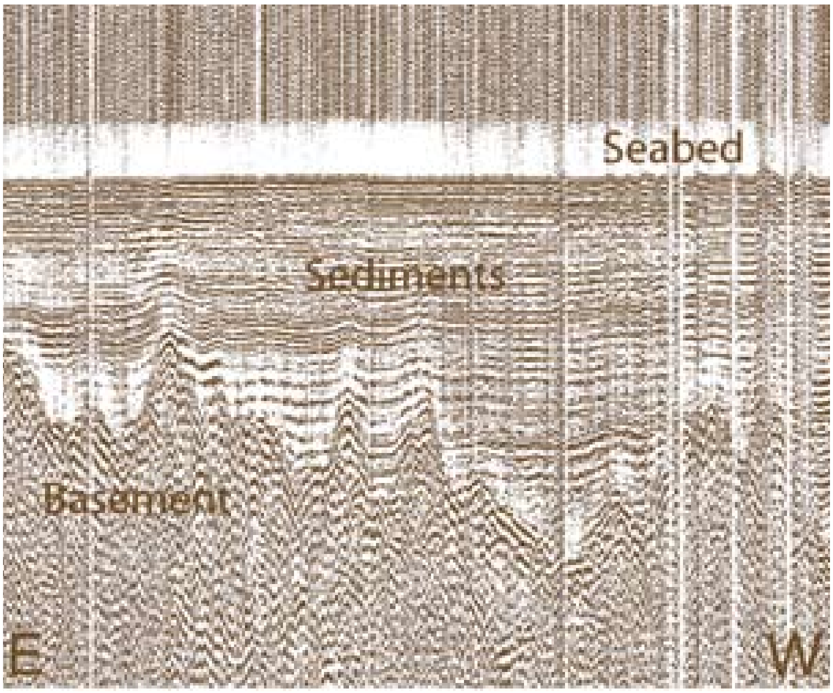

Figure 3
Part of seismic line acquired in the Amundsen Basin (water depth approximately 4 000 m).

Bathymetric data acquisition

During LOMROG, bathymetric data were recorded continuously along the ship's passage. The areas of specific bathymetric interest to the Danish Continental Shelf Project were:

a) the Amundsen Basin,
b) the slope of the Lomonosov Ridge, where the exact location of the foot of the continental slope was identified,
c) the crest of the Lomonosov Ridge, where the general outline of the Lomonosov Ridge was mapped and verified,
d) the zone where the Greenland shelf and the Lomonosov Ridge connect, for which very few bathymetric data exist,
e) the Morris Jesup Rise, where the precise location of the foot of the slope was mapped,
f) and finally, the East Greenland Ridge, where a high-resolution full-coverage multibeam survey was carried out in order to reveal the morphological features of the shelf-ridge complex.

Data quality was very dependent on the ice conditions. At the Lomonosov Ridge, where the ice thickness was up to 4 m with abundant pressure ridges, it was impossible to acquire data during ice-breaking and hence, alternative hydrographical surveying methods had to be employed (e.g. the "pirouette method", see Jakobsson et al. this volume). These methods are, however, more time consuming.

The East Greenland Ridge survey area was partly in open water and partly covered by polar drift ice. The data coverage was almost 100% in all areas including the outer shelf, the slope, the abyssal plain and the central part of the East Greenland Ridge. Five lines extending from the upper shelf break and across the ridge were surveyed with the multibeam echo sounder. Figure 5 shows a bathymetric map that was compiled from portions of two of the surveyed multibeam lines. The multibeam data from the East Greenland Ridge reveal important details of significant value for the interpretation of the area and for planning of additional work.

Gravimetric data acquisition

Gravity measurements were carried out with a marine gravimeter of type Ultrasys Lacoste and Romberg (Serial no. S-38). The gravimeter was

Figure 4
Left: 50 let Pobedy under way alongside Oden to break the ice.
Right: 50 let Pobedy reversing to "pick up" Oden.
These operations occurred often during seismic data acquisition due to the severe ice conditions in the area of investigation.
Photos: Thomas Vangkilde-Pedersen.

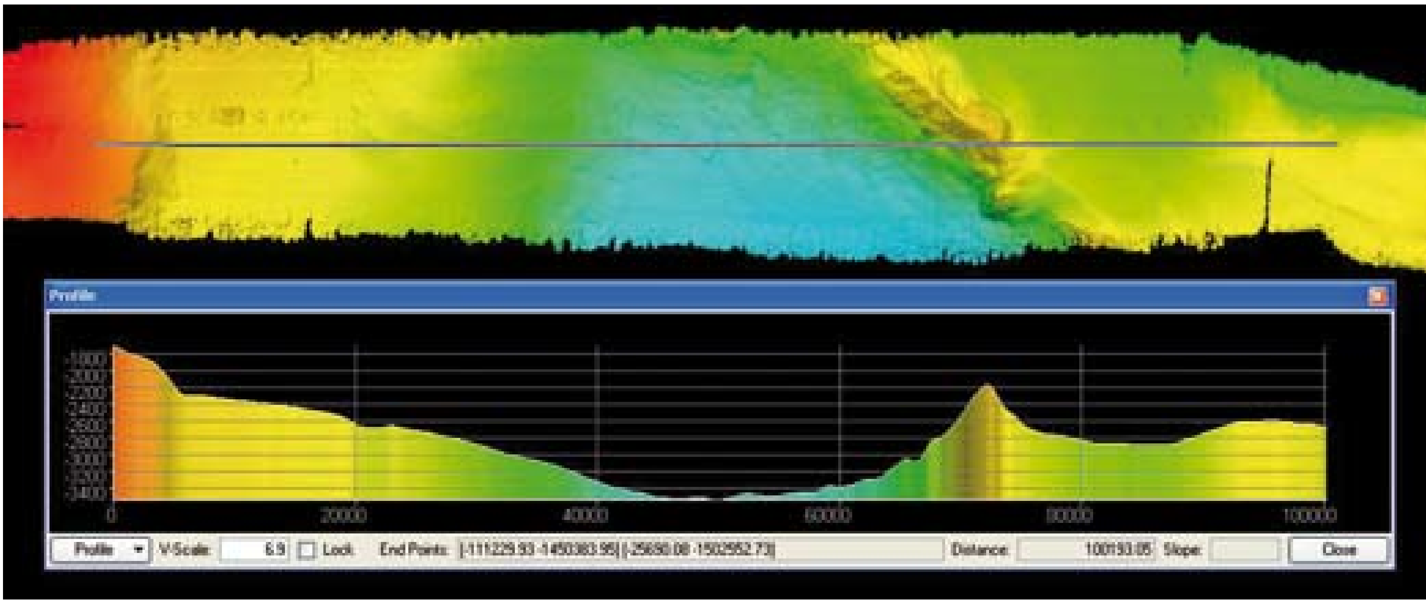

Figure 5
Top: Part of the bathymetric grid in the East Greenland Ridge area based on two of the surveyed multibeam lines. Bottom: Bathymetric profile – units in meters.

Figure 6
Marine gravimeter mounted in the engine room on board Oden. Photo: Rene Forsberg.

mounted in the engine room close to the centre of mass of Oden (Fig. 6). The system records data every 10 sec, which after processing and reference measurements in the harbours of Tromsø and Svalbard yield gravity values at an accuracy of approximately 1 mgal and 2–500 m resolution, depending on the speed of Oden and ice conditions.

As a complement to the marine gravity data, the ship's helicopter was used to make measurements with land gravimeters along profiles across the flanks of the Lomonosov Ridge and the Morris Jesup Rise (Fig. 7).

Gravimeter data collected on Oden were processed using the DNSC marine software "eotvos", that incorporates Eötvös corrections from the ship's GPS navigation (logged at 5 s intervals), outlier and spike detection, and a zero-phase filtering scheme. Some minor data gaps occurred for a short period of time due to some serial communications problems. However, most gaps were sufficiently short (a few minutes) to allow interpolation.

Oden provided an excellent platform for marine gravity measurements, and measurements in the ice were superior to data from many other icebreakers or even submarines, in spite of the irregular navigation with frequent course and speed changes. The Ultrasys Lacoste Romberg gravimeter employed proved stable and reliable with only a small drift and the gravimetric data collected will be useful both in connection with the Danish UNCLOS project, as well as an important new data contribution to the Arctic Gravity Project (http://earth-info.nga.mil/GandG/wgs84/agp/hist_agp.html).

The helicopter measurements were swift and efficient, but limited by the range of the helicopter and by the weather (frequent white-out conditions). However, with a functioning echo sounder and an increased operation range, this could be an efficient way to collect relevant additional geophysical data on future cruises.

Other activities

A research project with the aim of investigating and quantifying the importance of sea ice in transporting carbon dioxide from the atmosphere to the ocean in areas with different types of sea ice has been associated with the Danish part of the LOMROG cruise (see Rysgaard et al. this volume for details). Furthermore a Danish film crew (Suvi Helminen and Kenneth Sorento) from STV Nature and Science was stationed on board Oden during the LOMROG cruise to document the project and the cruise.

Conclusion

The LOMROG cruise demonstrated that acquisition of bathymetric and seismic data of sufficient quality for substantiating a claim according to article 76 of UNCLOS by a two ship operation is possible under the severe ice conditions that prevail in the area north of Greenland, and data acquisition would not have been feasible without the competent support from the Russian nuclear icebreaker 50 let Pobedy.

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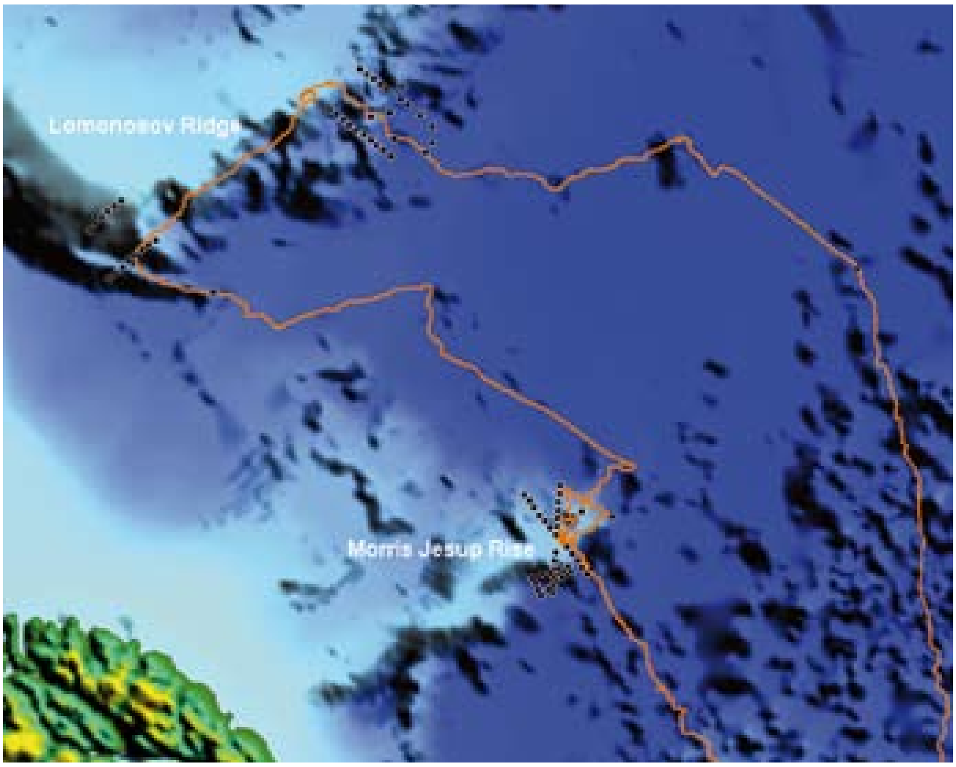

Figure 7
Location of the off-ship helicopter gravity profiles. Greenland at lower left.

LOMROG: Det danska Kontinentalsockelprojektet
Den danska delen av expeditionen LOMROG var ett led i Kontinentalsockelprojektet, som har till uppgift att ta fram det tekniska underlaget för en eventuell utvidgning av det danska territoriella kontinentalsockelområdet norr om Grönland, utöver de 200 sjömil som man idag gör anspråk på i enlighet med FN:s Havsrättskonvention.

Isförhållandena i undersökningsområdet hör till de svåraste i den Arktiska oceanen och utgör en stor utmaning för datainsamlingen. Syftet med LOMROG var således att testa datainsamlingskonceptet under dessa svåra isförhållanden och speciellt den nyutvecklade seismiska utrustningen.

Under LOMROG expeditionen insamlades följande data:
- Batymetriska data i Amundsenbassängen och upp på Lomonosovryggen, en batymetrisk kartläggning av yttersta spetsen på Morris Jesup-platån samt en kartläggning av det område där Östgrönlandsryggen möter den östgrönländska shelfen. Insamling av multibeamdata och subbottomprofiler har skett i tätt samarbete med de svenska forskningsgrupperna.
- Seismiska data längs en ca. 130 km lång profil i Amundsenbassängen, en 15 km lång profil på sydspetsen av Lomonosovryggen samt en 165 km lång profil vid Östgrönlandsryggen.
- Under hela expeditionen samlades kontinuerligt gravimetriska data samt gravimetriska punktdata med hjälp av Odens helikopter.

LOMROG-expeditionen har visat att insamling av batymetriska och seismiska data som kan användas i det danska Kontinentalsockelprojektet är möjligt trots de svåra isförhållanden som råder i området norr om Grönland. Datainsamlingen skulle dock inte ha varit möjligt utan den mycket kompetenta hjälpen från den ryska isbrytaren 50 let Pobedy.

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Lomonosov Ridge off Greenland (LOMROG) 2007: Sea ice and climate

The Arctic Ocean plays a critical part in global oceanic circulation, in that it modulates the formation of deep water in the North Atlantic via ice formation. The extent of Arctic sea ice undergoes seasonal changes with an average maximum of 15×106 km^2 and an average minimum of 8×106 km^2 (Gloersen and Campbell 1991). Due to warming of the world oceans (Levitus et al. 2000) the sea ice cover in the Arctic has decreased by ~10% in extent since the 1970s (Johannessen et al. 1999). Climate change due to the anthropogenic greenhouse emission is expected to be significant and relatively large in the Arctic region compared to other areas in the world and the consensus view is that within 70 years, the average annual temperature of the Arctic is predicted to increase by at least 4°C and in some places by more than 8°C. This increase implies that the sea ice thickness and distribution in the Arctic will decrease markedly and thus alter the heat and mass exchange as well as ocean stratification in the future and hence, research in sea ice areas is urgently needed in order to obtain a basic understanding of the processes and organisms being affected by the expected dramatic alterations in sea ice distribution.

Deep-water formation in the Arctic Ocean and the Greenland Sea contributes to the overflow water in the Denmark Strait and the Faroe Bank Channel (Buch et al. 1996, Hansen et al. 2001), which constitutes the origin of the North Atlantic Deep Water (Reid and Lynn 1971). In addition, high-latitude areas act as a sink for atmospheric CO_2 and thereby represent a direct pathway for CO_2 exchange between the atmosphere and the deep ocean (Takahashi et al. 2002). The difference between pCO_2 in surface water and the overlying air represents the thermodynamic driving potential for air-sea CO_2 gas exchange, which influences the surface concentrations of dissolved inorganic carbon (DIC). Surface-water pCO_2 levels are regulated by temperature, salinity and DIC and total alkalinity (TA) concentrations. DIC and TA have hitherto been considered to be controlled primarily by biological processes (i.e. photosynthesis, respiration and calcification), upwelling of subsurface water enriched in respired CO_2 and nutrients, and air–sea exchange (Takahashi et al. 2002). However, our recent work suggests that besides oxygen, DIC is also rejected from growing sea ice together with brine (Glud et al. 2002, Rysgaard et al. 2007). In addition, we have observed very low DIC and TA concentrations in Arctic first-year and multi-year sea ice as well as significant fractionation of DIC and TA compared to surface-water conditions (Rysgaard et al. 2007). Downward rejection of CO_2 from growing sea ice together with brine has not been considered previously, and nor has the resulting atmosphere-ice-ocean exchange of carbon resulting from this sea-ice driven DIC pump been quantified. Our first preliminary model calculations show that this DIC pump affects the surface-water pCO_2 significantly

Figure 1
Drilling ice cores with Kovacs drill at 85°N. Photo: Hans Ramløv.

in the polar seas and potentially sequesters large amounts of CO_2 in the deep ocean. Brine-mediated DIC transport into the deep ocean may be significant in the global carbon cycle, and variations in sea ice formation under past climatic conditions might help explain variations in atmospheric CO_2 levels.

A number of studies have revealed that ice algae can modify their environment in the sea ice so that they are able to exploit the interior of the sea ice as a habitat. The modifications are presumed to be mediated by the algae synthesizing ice active substances that at least can inhibit the growth of the ice surrounding the algae, but which possibly also widen the spaces by a non-colligative melting of the ice surface around the algae. The substances synthesized by the ice algae have several properties in common with the so called "antifreeze proteins" that are synthesized by a number of cold tolerant ectothermic animals. These proteins can recognize ice surfaces and bind to them, and are thereby able to inhibit the growth of ice crystal. To understand the total CO_2 budget of the sea ice, investigations of these ice associated algae and their physiology is needed. Likewise, future decrease in global sea ice cover may reduce the world oceans' capacity for taking up atmospheric CO_2. Assessing changes in future sea ice conditions as projected by climate models will allow for a more quantitative analysis of this hypothesis. Thus, more research on this process is urgently needed.

Aim

The aim is to investigate and quantify the importance of sea ice in transporting carbon dioxide from the atmosphere to the ocean in areas with different types of sea ice. Furthermore, our recent discoveries of anoxic conditions and bacterial denitrification/anammox activity in sea ice show that sea ice may play an important role in the removal of nitrogen. More investigations from multi-year sea ice are, however, needed to increase our understanding of its significance in the Arctic and its role in the global nitrogen cycle. Furthermore, sea ice formation may play a far more important role in transporting carbon dioxide (CO_2) from the atmosphere to the ocean than previously assumed. Our preliminary studies on first-year sea ice from northeast Greenland and northern Canada have indicated that ice growth during winter rejects large amounts of CO_2, which sink together with dense brine to intermediate and deep water layers. Subsequent sea ice melt during summer enhances the uptake of CO_2 from the atmosphere, as the resulting meltwater is undersaturated with respect to CO_2. As the transport mechanism is dependent on sea ice formation, future decrease in global sea ice cover may reduce the oceanic capacity for taking up atmospheric CO_2.

During the LOMROG expedition, sea ice samples were acquired by drilling ice cores along the expedition path with the aim of measuring the total concentration of inorganic dissolved carbon (TIC or TCO_2) and total alkalinity (TA). In addition to the physical and chemical measurements of the sea ice, the occurrence of algae in the ice was also investigated. The reason for this is that the role of the algae, concerning the chemical conditions in the context of the CO_2 in the ice, is not well known. Thus it is of importance to investigate the algae and their physiology. Ice algae synthesize some substances that can modify the ice surface and optimise the environment in the ice in which the algae are found. It is therefore also one of the aims of the present study to investigate the algae and the synthesized substances.

Methods

Ice coring

Different types of sea ice were collected using a 7 cm KOVACS ice core drill fitted with a battery driven hand drill. 10 cm pieces from the top, middle and bottom of the ice core were cut out and transferred to plastic containers. Before collecting the 10 cm pieces the temperature along the core was measured at 10 cm intervals.

Physical measurements

The physical parameters air temperature, snow depth, snow temperature (5 cm intervals), ice surface temperature, ice density and total ice salinity (melted ice core) were measured at each drill hole and ice core piece.

Density of the core pieces was determined from top, middle and bottom, where possible, by measuring and weighing the core piece.

Preparation of ice cores for measurements of TCO_2, total alkalinity (TA), salinity and chlorophyll a

The collected core pieces were taken to the laboratory and cleaved. One half was transferred to a gas proof plastic bag (Würgler bag (Würgler Hansen et al. 2000)) and sealed. The ice was melted in the bag and the melt water

Figure 2
Taking ice core samples for the measurement of CO_2 and alkalinity in the sea ice at 85°N. Photo: Hans Ramløv.

transferred to gas tight containers, preserved with $HgCl_2$ and then brought to the laboratory in Nuuk (Greenland) where the final measurements are to be done.

The other half was melted; some melt water was transferred to a plastic vial for the measu-re-ment of salinity and the rest was filtered through a glass filter and the filter was thereafter frozen for the later determination of the chlorophyll *a* content of the filtrate (i.e. the ice). In addition to the ice cores, water samples from 10 m depth were acquired from the CTD that was operated by one of the Swedish groups participating on the expedition (see Andersson and Björk in this volume).

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LOMROG: Havsisen och klimatet

Den Arktiska oceanen spelar en viktig roll i den globala havscirkulationen. Bl.a. påverkar den bildningen av bottenvattnet i Nordatlanten via isbildningen på hösten och vintern. På grund av den globala uppvärmningen har istäcket i den Arktiska oceanen krympt med ca 10 % sedan 1970-talet. Det förutspås att under de nästkommande 70 åren kommer temperaturen i den Arktiska oceanen att stiga med mellan 4°C och 8°C, och på det följer ett ytterligare minskande istäcke.

Då havsområden på höga breddgrader fungerar som magasin för atmosfärisk CO_2, och då upprinnelsen i det nordatlantiska djupvattnet är ”överflödet” från djupvattnet i Danmarkssträdet och Kanalen vid Färöbanken, är dessa direkt medverkande till överföringen av atmosfärisk CO_2 (koldioxid) till djuphavet. Den drivande kraften bakom utväxlingen av CO_2 mellan luft och vatten är skillnaden i CO_2-partialtrycket mellan vattnet och den överliggande luften. Ytvattnets CO_2-partialtryck bestäms av temperatur, salinitet, upplöst oorganiskt kol (DIC) samt den totala alkaliniteten (TA). Tidigare har man antagit att DIC och TA kontrollerades av den fysiska nerkylningen av vattnet samt av biologiska processer, men det har visat sig att CO_2 skiljs ut under isbildningen och upplöses i det salta vattnet som blir till som en följd av fryskoncentrationen i fickor i isen (brine-bildning). Denna mekanism kan ge anledning till en stor förflyttning av mycket salt och CO_2-berikat vatten till de djupliggande vattenlagren, som inte tidigare har funnits med i modellberäkningar över CO_2-utväxlingen i Arktiska oceanen. Under LOMROG-expeditionen samlades 28 × 3 iskärnor, vari TA, DIC och salinitet blev undersökt. Ytterligare ett antal iskärnor samlades in och transporterades i fruset skick till Grönlands Naturinstitut. Där ska de användas till undersökningar av isens pH-värde, innehåll av kalciumkarbonat och isalgernas inflytande på isens CO_2-innehåll samt hur isalgerna påverkar isytan där de finns.

Polarforskningssekretariatet är en statlig myndighet med uppgift att främja och samordna svensk polarforskning. Det innebär bl.a. att följa och planera forskning och utvecklingsarbete samt organisera och genomföra forskningsexpeditioner i Arktis och Antarktis.

Polarforskningssekretariatet är förvaltningsmyndighet för lagen (2006:924) om Antarktis och prövar frågor om tillstånd för vistelse eller verksamhet i enlighet med lagen.

The task of the Swedish Polar Research Secretariat is to promote and co-ordinate Swedish polar research. This means e.g. to follow and plan research and development and to organise and lead research expeditions to the Arctic and Antarctic regions.

The Swedish Polar Research Secretariat is the administrative authority for the Act on Antarctica (2006:924) and handles permit issues for visits or activities in accordance with the Act.

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