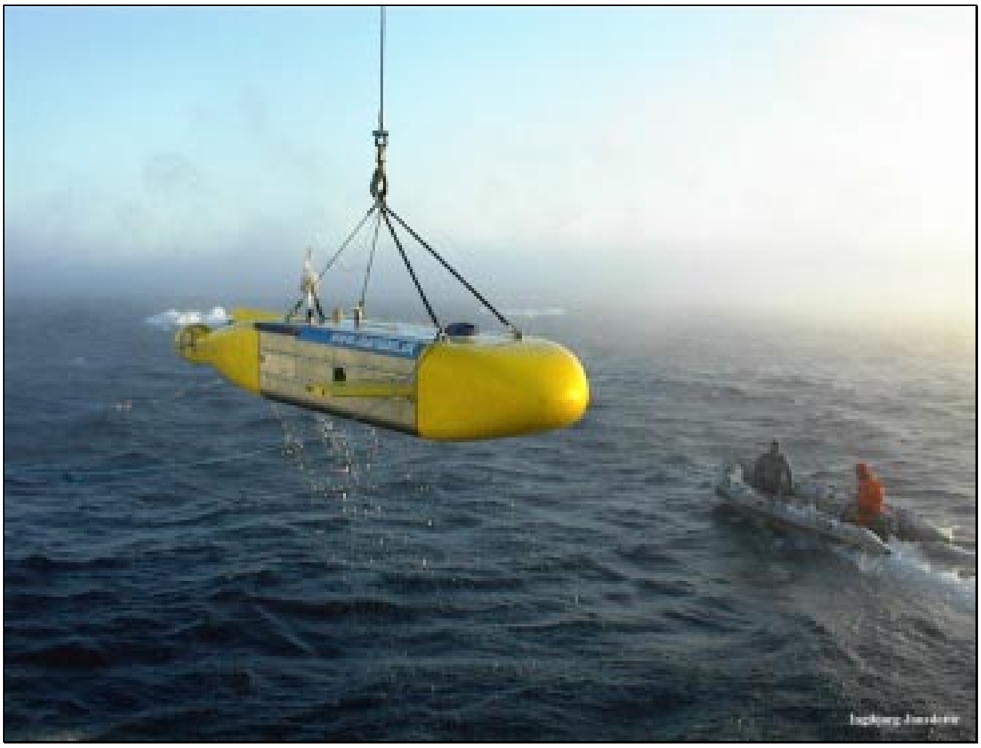
RV "Lance" Cruise Report

14 February to 10 March 2002



CONVECTION
Ocean-ice physics cruise to the central Greenland Sea

by

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Introduction

The second winter CONVECTION cruise of RV 'LANCE' (February 14 – March 10 2002) was funded by the Commission of the European Communities, Environment and Climate Programme, as part of the CONVECTION project (2001-3). The ten partners in the project are listed below; three partners participated in the cruise. The purpose of the project is to study the physics of ice-ocean interaction in the Greenland Sea in order to understand winter convection and the reasons for its variability. Oceanic convection is a process of critical importance for our understanding of climate and climate fluctuations, particularly in the North Atlantic region and NW Europe. The project is a successor to the EU's ESOP-1 (Wadhams et al., 1999) and ESOP-2 projects (Jansen et al., 2000) of 1993-6 and 1996-9 respectively, and also complements national programmes. The cruise is a successor to earlier winter cruises, particularly the March 1997 "Jan Mayen" cruise to the same region, funded by the EU ESOP-2 programme, a German "Valdivia" cruise in 1999; an Anglo-German-Norwegian cruise in "Jan Mayen" in February-March 2000 (Wadhams et al., 2000), and a German cruise in "Jan Mayen" in March 2001 in which the CONVECTION programme was invited to take up berths. The first CONVECTION winter cruise in "Lance", to which the present cruise is a direct follow-up, was carried out in April 2001.

The 2002 CONVECTION cruise had the following mutually interactive scientific aims:

1. Determination of the winter 2002 hydrography of the central Greenland Sea gyre region, including the location and depth of convective events, and the structure of the Jan Mayen Current, especially where it emerges from the East Greenland Current;
2. Determination of the distribution and role of sea ice in winter processes in the region.

In practice it was known from remote sensing imagery that the Odden was not developing strongly and would not reach the central gyre region in winter 2002. Therefore the two aims were decoupled, and instead of the ice work and hydrography being carried out together, the cruise focused primarily on the hydrography of the central gyre, where a unique deep convective cell reaching beyond 2500 m, discovered during the previous winter, was found to still exist in the same location after a year and was resurveyed. A separate phase of the cruise took the ship into the part of the marginal ice zone which contained pancake ice and which was the source area for Odden. A unique feature of the cruise was the inclusion of an AUV, the Maridan Martin 150, which obtained the first under-ice profiles ever achieved by an AUV in the Arctic.

The cruise can be divided into three stages, which are described more fully in the Narrative and Results sections. They were:

1. An initial attempt to relocate the 75ºN/0ºW chimney, cut short by bad weather.
2. An ice-ocean physics programme along the East Greenland ice edge from 73º 30'N to 72ºN, to compare hydrographic structure to the position of the ice edge, nature of the ice cover and presence and extent of young ice growth within the East Greenland ice regime. This involved physical retrieval of pancake and frazil ice for determination of salinity and ice crystal fabric; and, for the first time in the Arctic, under-ice profiling carried out by the Maridan AUV. The work was guided by SSM/I, Radarsat, ERS-2 SAR and AVHRR and satellite imagery of the ice edge received on board by downloading information supplied on a Web based software package by a partner,

Danish Technical University. CTD profiling and water sampling continued during this phase. AVHRR imagery was supplied by the Dundee receiving station (UK) and processed and sent to the ship by our Italian partner (ISAO-CNR)

3. A return to the 75°N 0°W region to rediscover the convective cell and to carry out an intensive CTD and current meter survey to define its structure and internal dynamics, with a grid of 9 stations 3 nml apart. An APEX float was also deployed at the centre of the chimney for long-term monitoring of its further development. Bad weather prevented more extensive work.

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In this preliminary cruise report we present results from the CTD surveys and ice salinity analyses, together with descriptions of the other measurements that were carried out.

Partners in the CONVECTION project

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Danish Technical University, Lyngby, Denmark
IFREMER, Brest, France
Alfred-Wegener-Institut für Polar-und-Meeresforschung, Bremerhaven, Germany
Institut für Meereskunde, University of Hamburg, Germany
*Science Institute, University of Iceland, Reykjavik
ISAO-CNR, Bologna, Italy
*Norsk Polarinstitutt, Tromsø, Norway
Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK

Associated contractor: ITIS-CNR, Matera, Italy
*Subcontractor to SPRI: Maridan A/S, Copenhagen, Denmark.

* Personnel took part in cruise.

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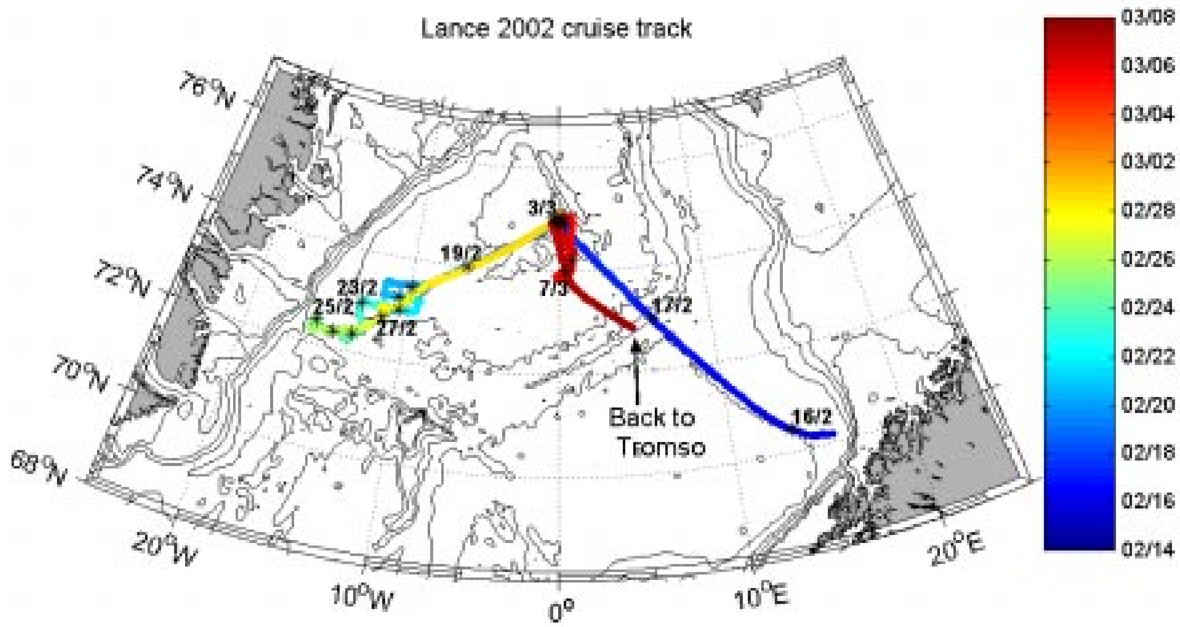
Cruise track



Schematic showing the cruise track of Lance during the winter 2002 CONVECTION cruise.

Scientific setting

With regard to changes in the hydrography and ice conditions in the Arctic Ocean and Nordic Seas it is only recently that the importance of the North Atlantic Oscillation (NAO) has been discovered. The NAO, itself part of an Arctic-wide fluctuation known as the Arctic Oscillation (AO), is described by an Index which quantifies long term fluctuations of the air pressure gradient between the Azores and Iceland. If the NAO index is high, as during the entire 1990s to the present day, low pressure systems over the North Atlantic are very energetic, and they transport more heat from sub-tropical into polar regions than the long term average. In the course of this change an increase in significant wave height in the Nordic Seas has been observed. With the NAO being high the persistent high pressure system which, normally, is situated over the ice masses of Greenland is shifted to the west. As a consequence, northerly winds over the Greenland Sea are much warmer than with the Greenland High in place. This large scale shift in the northern hemisphere atmospheric pressure distributions, typical of a high NAO, causes the Labrador Sea to receive an increased cooling from cold northerly winds brought about by the Greenland High. The Greenland Sea in turn receives much less cooling than on average because energetic Lows sweeping over the Nordic seas import too much heat to polar regions. As a consequence the centre of activity of deep reaching oceanic convection changes from the Greenland to the Labrador Sea when the NAO index is high, and vice versa. Whilst in most regions of the north Atlantic and Nordic seas a direct response of oceanographic properties to the NAO can be observed the Greenland Sea appears to behave anomalously. The only significant and clearly discernible response of the Greenland Sea to an NAO which has been high for more than 10 years is a general warming and an increase in salinity of deep and intermediate waters. This is a consequence of the still-weakening oceanic convection in the Greenland Sea. The properties of Greenland Sea surface waters, however, including the ice cover, do not show as close a correlation with the NAO as is found elsewhere.

For the past ten years no significant deep oceanic convection had been observed to occur in the Greenland Sea. On average only about 2% of the cold and low-salinity outflow of upper Arctic halocline waters which emerge through Fram Strait with the East Greenland Current (EGC) are imported to the Greenland Sea with the Jan Mayen Current. These waters form the so-called ‘fresh-water’ layer of the upper Greenland Sea. With oceanic convection being active the cold and low saline surface waters are brought to greater depth which explains why the Greenland Sea deep waters are normally characterised by their cold and fresh properties. A missing convection under a high-NAO regime causes a decrease in this vertical transport. Throughout the 1990s we observed that the Greenland Sea deep-water masses were becoming warmer and saltier. This, however, cannot be explained by the missing convection. A lateral import of both heat and salt from neighbouring seas is prohibited due to high topographic sills around the central Greenland Sea. The mechanism which accounts for the described change of deep water mass properties is as yet unknown.

The import of Arctic ‘fresh water’ to the Greenland Sea with the Jan Mayen Current can be visualised by a buoyant wedge which leaves the EGC to the north of the Island of Jan Mayen. It flows, and floats at the sea surface, in a spiralling and cyclonic motion around the Greenland Sea basin. Under normal climatic conditions this buoyant wedge is very cold, i.e. the temperatures of the waters are close to the freezing point of sea water. The strong density contrast between the wedge and underlying warmer water masses effectively prevents an exchange of heat. Differential cooling in a thermally-isolated shallow-water body floating on the surface of the Greenland Sea favours the production of young sea ice in the open ocean, far away from the main body of the EGC. This explains the existence of a protruding ice tongue in the Greenland Sea which is called ‘Is Odden’ or more usually just ‘Odden’. Since the 18th century it has been a feature well known to whalers and sealers.

Historically, it is rare to have a winter without the development of an ice tongue in the central gyre region. During the 1970s and 1980s, for instance, only 1984 was Odden-free. During the 1990s, however, the absence of ice has become more frequent. 1994 and 1995 were both Odden-free, while in 1996 an ice tongue developed only in spring and summer and was composed of old ice advected out of the East Greenland Current rather than new locally-formed ice. Odden tongues formed in 1997 and 1998, but 1999 was again Odden-free as was the winter of 2000. It appeared that an important regional climatic switch had occurred, and the challenge was to determine whether the cause is thermal (general global warming or enhanced regional warming precluding ice formation), meteorological (e.g. a high North Atlantic Oscillation index indicating a predominance of warm easterly winds over cold W and NW winds), or oceanographic (e.g. a change in the volume or composition of the Jan Mayen Current, which normally provides the cold surface water needed for ice formation). This cruise offered a unique opportunity to test hypotheses on the causes of these recent changes. The implications of the changes have already been spelled out by modellers in that a shut-off of convection will ultimately lead to a lesser oceanic poleward heat transport by the Atlantic thermohaline circulation and thus a cooling of NW Europe during winter.

In the event, 2001 proved to be an extraordinary year which may have represented a turning point. The Odden ice tongue returned after a 3 year absence, although not as extensive as in some earlier years. Most important of all, convection down to beyond 2500 m was discovered in the form of a narrow chimney, which has not been observed experimentally since the early 1970s. It is now of great importance to try to understand what has caused this return to the conditions of 30 years ago; hence the value of the 2002 cruise.

Frequent visits of oceanographers to the Greenland Sea in the 1990s have revealed that the import of fresh-water to the Greenland Sea is highly variable. Hatten (pers. com. 2000) found that it is not correlated with the fluctuations of the NAO. It was further noted on a number of “Valdivia” cruises to the Greenland Sea that the temperatures of the thin ‘freshwater’ surface layer (observed thickness: in the order of some tens to a few hundreds of meteres) have increased as compared to the 1970s and late 1980s. Surface temperatures were no longer close to the freezing point of sea water (ca. –1.85°C) as usual, thus constituting a condition unfavourable for ice formation within the buoyant wedge. At present, without knowing the exact reasons, we conclude that the anomalous conditions in properties of Greenland Sea surface waters, including sea ice, are induced by a strong variability in the freshwater import with the Jan Mayen Current, and by a trend towards a warming of the waters in the ‘freshwater’ wedge. The latter could be a consequence of the increased import of heat with the atmosphere during phases of high NAO. However, one would expect that an increased import of heat to the Arctic Ocean would cause an increased outflow of freshwater with the EGC due to an increased melting of sea ice, and an enhanced import of freshwater to the Greenland Sea with the Jan Mayen Current. Apparently, this is not observed, and the reasons are as yet unknown.

The changes described above in sea ice conditions, oceanic convection, and properties of deep and surface waters in the Greenland Sea, formed the scientific setting for the CONVECTION winter cruise and the CONVECTION project.

Voyage narrative

The main characteristic dominating this voyage was the weather. It was persistently bad, with a succession of northerly gales of Force 10 or more which prevented CTD work, and which overlapped in effect so that there were few “weather windows “ in which station work could be done. We overcame this to some extent by moving to the ice edge and doing our ice work during the worst of the storms, but still had to ride out extensive periods in the convective chimney region waiting for conditions to ameliorate.

The weather also had a destructive effect on the work of RV “Aranda”, with which we had planned to collaborate. She was carrying out a cruise for the University of Hamburg (J. Holfort, chief scientist) which was meant to include a survey of the convective chimney. In the event she could only do two CTD stations during her entire voyage (19-28 February) and was therefore unable to complement our own work.

Phase 1: Initial work at 75°N

All times given are European time (UTC + 1).

RV “Lance” left the port of Tromsø on February 14, one day later than planned because of problems with the autopilot and with a requirement by Maridan to attach a sonar tracking system to the ship’s side. She began in the fjord nearby carrying out a calibration study for the sonar tracking system, after which the sonar engineer was put ashore during the night and the ship sailed, heading north-west towards the Greenland Sea.

An immediate Force 10 gale slowed the ship’s progress towards her first goal, the convection region at 75° N, 0° W. The SPRI IceCam stop-action video system had been set up in the crow’s nest in Tromsø and was recording the scene ahead automatically as it would do until the end of the voyage. Since meteorological parameters are not recorded automatically on the ship, to estimate ocean-atmosphere heat fluxes we needed to devise a scheme for measuring 8 parameters off the bridge every hour and writing them in a log.. This involved beginning a watch system for the SPRI group. The parameters are air and water temperature, pressure, humidity, wind speed and direction relative to ship, and ship speed and head.

We reached our **first station** (2001), at 74° 53’N, 0° 17’E., at 1330 on February 17. Water depth was 3600 m. This position was chosen as the centre of a search area for the 2001 convective chimney, because it was the centre of the chimney as of October 2001 when it was most recently surveyed by V Pavlov aboard “Lance”. However, at the site the depth of convection appeared to be only about 1500 m.

We them moved eastward, to the **second station** (2002), at 74° 53’N, 0° 29’E. we found that we were even further from the centre, with convection only going to 1200 m. I decided on NW, to a station numbered 18 in our 3-mile planning grid, at 74° 56’N, 0° 17’E. But by now our window of good weather was ending. The sea was coming up, with a NE force 9 gale forecast for the following evening. It was clear from weather maps and forecasts received via Danish Technical University that the sea would get steadily worse and stay too rough for CTDs for at least 72 hours. On the other hand we could still steam. Therefore there seemed no alternative to sailing off to the ice edge to do the ice work at this stage, hoping to complete our convection cell survey on our return. We therefore left the survey area on February 18 and headed SW.

At each of the stations within the convection region, on behalf of Prof Jean-Claude Gascard (Université Pierre et Marie Curie, Paris) we collected water samples at nine depths for a study of iodine-129 tracer. In addition we collected water samples at the same depths for oxygen-18 determination.

Phase 2: Ice edge physics

February 19

We headed first for the Vesterisbanken, a shallow seamount at 73° 30’N, 9° 00’W with a crest depth of only 123 m, where Barry Uscinski (DAMTP) had deployed his acoustic array in October 2001 for detecting convective plumes. The array needed to be surveyed for validation purposes, and the most recent ice chart showed that pancake ice had reached this longitude.

On February 19 we entered pancake ice at 0330. Our position at 0508 was 73° 31.1’N, 8° 56.2’W. The ice consisted of very large, old pancakes in clusters. We would pass through a dense patch, of close pancake in all directions, then would come a gap and an area of diffuse pancake. The sea was damped down to a large swell.

We planned three stations over Vesterisbanken, each corresponding to one of Uscinski’s sites, but each about 1/3 mile south of it, to avoid any danger of entangling. The positions, and Uscinski’s positions, were

Uscinski	Our station
73° 31.32‘N, 9° 03.75’W	73° 30.8’N, 9° 03’W
73° 33.45’N, 9° 02.219’W	73° 33.1’N, 9° 02’W
73° 30.65’N, 9° 07.51’W	73° 30.3’N, 9° 07’W

We reached the first station, actually the furthest SW (third on list), at 0545. This was in a dense band of pancakes. The CTD was deployed first, then the hatch was opened to unload the Zodiac (needed for AUV setup) and the ice lifter. The CTD went to about 700 m and showing a mixed polar surface water layer 150 m thick.

At 0830, in the same position, we started our first ice station. We did a pancake lift (pancakes 1 and 2), a stick throwing session, and six frazils. The AUV being not yet ready, at 0945 we moved to the position of the second mooring site (first on list), a little to the NE. Here we did an ice lift, raising pancake 3 (very large and thick) and 4 (small but still thick), having reached site at 1000. Again at the site we did 6 frazils and stick photos. A CTD was done.

At 1200, the AUV still not being ready, we moved to the third Vesterisbanken site (second on list), to the NE. We reached it at 1300, and did an ice lift and a CTD.

By 1440 the station was done and the ice sampling complete through a second ice lift. It was decided that there was too much swell to put the AUV in the water, so we had the ship sail due W for one hour, passing through an assortment of pancake ice. At 1535 we stopped at 73° 29.81’N, 9°26.49’W. Here the AUV went into the water and was ballasted for the Greenland Sea. First the Zodiac went into the water. Then the AUV came out of its heated container on a trolley, and was lifted up and over and into the water by the starboard foredeck crane. It was controlled from deck by a radio control unit. From the dinghy weights were added, and vertical posts screwed into the AUV so that its attitude in surface motion could be determined. The process took until 530, when all were recovered.

After the AUV work, an ice lift was done at the site, a CTD then another ice lift, then we moved W for 10 miles to start an E-W section during the night. The first site was 73° 30’N, reached at 2100.

On first entry into the ice we had begun an hourly ice watch, with video recording from the bridge, and an hourly description of the scene and photographs ahead, to port and to starboard. This is a well-proven formula tested in many Arctic and Antarctic cruises. A watch system for ice and met logging and ice work was set up, comprising 6-12 for Wadhams, Jonsdottir and Hughes; 12-6 for Wilkinson and Kaletzky. The 6-12 watch also assisted from 12 to 18.

February 20

We did one station overnight. At 0630 we came on to a new station at 73° 28.8’N, 11° 11.7’W. We started with an ice lift and recovered two small pancakes, 17 and 18. Then after the CTD we did a second ice lift, recovering a set of very small thin pancakes, only 3 cm thick and very weak. We did a stick throwing in the half light of pre-dawn and also found no local frazil growth. We moved the outdoors ice processing operations into the container lab on the foredeck.

We continued running to the W, with the bridge video running. There were almost no waves, so the growing ice could almost form nilas, actually forming interlocking pancakes which really count as a single sheet. Also we saw an increasing number of multiyear floes, with thick snow on top, showing that we were approaching the East Greenland pack ice, or were already in it. At 1010 we reached station at 73° 29.9’N, 11° 39.8’W. We did an ice lift, which produced pancake 26, a thick one with a rim. However, we found that the stop had been premature, so we sailed on until we reached the intended station position at 73° 30’N 11° 46’W. Here we began with another ice lift, recovering small thin pancakes. It was intensely cold, a real polar landscape. The temperature was –19ºC with a bitter wind blowing. A cold sun had come out, and those few areas that were not covered with thick ice (including ridges), pancakes or frazil, steamed with classic frost smoke, tinted pink by the sun.

The weather affected the CTD as well. The winch block froze, despite having a heater, and had to be unfrozen. The CTD proceeded and finished at 1420, and we did another ice lift before moving off. We recovered a big thick pancake (no. 30) that seemed to come in two sections, joined across the top but each composed of thick hard glassy columnar ice. I think these are two brash fragments incorporated into a pancake – in other words, we were into the same ice that we had found in the 2000 cruise, which looks like pancake but isn’t necessarily of pancake origin.

From this station we started S, heading 15 miles for 73° 15’N 11° 6’W. The idea was to come south then east, so as not to be too far from Vesterisbanken where we intended to do AUV transects looking for convective plumes. The AUV itself had various faults that made it unusable this day.

February 21

In the early morning we did a CTD station at 73° 14.1’N, 10° 00.4’W. At 0630 the CTD came up and we did an ice lift, recovering a large pancake, no. 40. We sailed E to the most easterly station of this section, at 73° 15’N, 9° 25’W (same longitude as first AUV test), which we reached about 0830. We did an ice lift, producing some classic pancakes (41-44) including one with a double rim which looked as if a smaller pancake had been enclosed and engulfed by a larger. In each case we cut them up with a photograph of the saw marks first, to enable the salinity values to be referenced to the appropriate part of the pancake.

The CTD was complete about 1030, then we did one more ice lift which produced a large inverted pancake. It was now time to try to use the AUV. The AUV was pulled out, lifted into the water and released, with the sonar tracker down. Unfortunately the AUV got washed into the starboard stern region of the ship by the stern thruster, and hit heavily. It then went off in a seemingly correct way, cutting through a field of dense frazil ice at the surface. Bo got it to follow a 1 km course, which it did, but dived (to 26 m) without orders. It seemed on surfacing to have a list to starboard. With difficulty, and by launching the dinghy, it was recovered about 1pm for repairs. The port aileron (forward hydroplane) was fixed in a full down position.

Repairs seemed likely to extend beyond daylight hours, so we set up a new station pattern to take us until the following morning, i.e. a run S by 15 miles to 73° N, 9° 25'W, followed by westward steps of 10 miles until it was time to return to the ice edge for dawn.

At 745 pm we came onto the next westward station, at 73° N, 10° 01'W. As we stopped we did an ice lift and got a small pancake, 48.The CTD started giving odd results, probably due to a frozen sensor, so was pulled in and we started off for the next station, intending to pick this one up on the way back. Before leaving we did another ice lift which produced a very thick double layer pancake, no. 49.

February 22

At midnight we were on station at 73° N, 10° 36'W, which worked well. We did an ice lift which yielded pancake no. 52. The ship went on to 11° 11'W, which was reached at 0400. Here the ice lift produced some pancake fragments only (pancakes 53, 54 analysed). At this point the strong winds predicted by the weather maps started to hit us. The wind speed rose to 43 kts, a really severe northerly gale. It blasted gritty pieces of granular ice through the atmosphere at any exposed flesh, and made the ice lift a misery. Because of the heavy dense pack of big pancakes, the CTD line was pulled sideways and the CTD was in danger of being lost, so the station was run to only 1000 m.

After the station we started heading E to find some open water for the AUV. However, by 0700 the wind situation was so bad that the ship was turned and started heading W and NW back into the pack. The Captain felt that the northerly gale would be stripping pancake ice away from the ice edge and demolishing it, so wanted to put as much ice as possible between us and the storm waves. The wind was too strong to do any work on deck, even ice lifting, so we concentrated on catching up with salinities. By 0900 we were well to the west, at 73° N, 11° 25'W. Ice conditions alternated. Sometimes we were in a very dense pack of mixed pancake and old ice, all smashed up and covered with snow, while at others we would emerge into open water regions, with wave growth clearly visible on the upwind side of the polynya thus identified. One of these was 2 nml across, with huge waves at the downwind end.

At 1530 we made an attempt to do an ice lift, but the biting wind and shortage of small pancakes halted us.

February 23

With the wind up to 40-50 kts we could do nothing but drift and/or motor gently around all day. Mostly we stayed within a sort of polynya 2-3 miles across, well within the pack, where we sat either in the open water watching the short-fetch waves kicking up a huge amount of spume and demolishing pancakes, or else in the pack where we looked out on a mix of old floes and smashed-up pancakes and brash. The wind was too strong for a CTD, and too strong to put anything over the side, even an ice lifter . All we managed all day was a set of 6 frazils. Our position at 2200 was 72° 22.8'N, 13° 04.2'W, the result of a southward and westward drift which has taken us well away from our operating area. Ice charts received this day showed that the ice in that area has in fact disappeared, and the proto-Odden bulge in the ice edge, containing the pancake ice, has been bodily moved south, as if by a gigantic broom. So if we wished to work in such ice again, we were in fact now at the right latitude although too far into the ice.

Remarkably, we were due to receive a Radarsat image this day, and were amazed to hear that the satellite had gone wrong and had failed to receive the image, the first-ever failure by Radarsat.

In late afternoon we did manage to take six more frazil samples.

February 24

We drifted SW overnight, reaching 72° 12.5'N, 13° 26.1'W by 0730. The air temperature at –10.1° C was a lot higher and the wind a little lower. But it was still too windy to work. We alternated between being in open water in the polynya, and pushing into dense polar pack ice at its edge.

Eventually, in late afternoon the wind started to go down a little and we were back in business. We were way to the west; at 1830 our position was 72° 29.5'N, 15° 35.6'W, far enough west to be in shallowing water (1900 m, not quite shelf). We started with an ice lift which yielded one large pancake (no. 55). Then we moved out into the open water, past an impressive ice mass which looked like an iceberg but was probably a multiyear floe with a worn pressure ridge at one end. Here we did a CTD, giving typical East Greenland Current structure with a polar water layer some 120 m thick, and a 2°C Atlantic water peak.

After the station the Captain was adamant that we should move north, so I laid out more stations at this longitude and at 15 mile northward intervals. We did another ice lift, yielding two small pancakes that had built themselves up around brash nuclei (56 and 57), and a huge lump of solid brash. For the first time ever there was a clear night: the moon, almost full, was shining in a sky full of stars, reflecting in the dark water and the white snow-covered ice floes.

North of us was solid pack, in which we got stuck and from which we had to be extricated by the Captain. Then we drifted south, as he said that it was unsafe to move.

February 25

During the night we tried various frazil sampling techniques from the drifting ship. At 0635 we had drifted to 72° 23'N, 15° 55'W. The wind had gone down to 17-19 kts but it had grown very cold, at –19.2°C. The moon was still shining, and later the sun rose to reveal a cloudless sky, remarkably, and an open sea with no sign of frazil but with massive amounts of frost smoke boiling off it and wafting about in great billows. It is likely that we had drifted into the Greenland coastal zone where we were now sitting in the cold air mass which lies over the island of Greenland, real polar air. The absence of frazil could be because the surface water had sensible heat in it (the bridge temperature sensor showed it 0.4°C above freezing), and this could be an upwelling onto the Greenland shelf due to the strong offshore winds from Greenland bringing us this frigid airstream. However the problem was to test this with a CTD.

At 0815 we did an ice lift, producing pancake 58, a classic pseudopancake, actually a large solid brash block on which a fringe of congealed frazil has accumulated. From above it looked like a large flat pancake. From the side we could see that it was old ice. Still, we sliced up the pancake part although the brash part was like solid glass and could not be sampled.

The scene was now dramatic, with the sun shining in different colours through the clouds of frost smoke. At 10 am we were ready to try our next AUV test. The vehicle had been ready for some time, waiting only for the wind to go down. With a calm sea (although bitterly cold wind, air temperature now down to –21 or –22ºC) all looked well. The vehicle was lifted into the water as before, and as before was immediately swept sternwards to bash against the ship's side near the stern. Reason? As before, the Mate had given a big blast with the stern thruster as soon as the AUV got in the water, to move the ship away from the AUV, but instead the undertow sucked the AUV against the ship. Again it was swept under the stern and emerged damaged.

The AUV was recovered using the Zodiac. The AUV was found to have damage to the rudder and the propeller casing, requiring fibre-glassing, a 24 hour task.

We wished to do a CTD at this spot but could not as the block for the winch line was frozen. Therefore, to test the idea that we were in a coastal upwelling zone we decided to try lowering our own portable Seabird CTD. At 1413 the ship, which had set out NE wards, was stopped and the Seabird lowered on 50 m of line. It indeed showed some heat in the water column, with an SST of some –1.5°C, but also the pressure sensor seemed to be malfunctioning, something unheard-of for a Seabird. The position was 72° 15.11’N, 15° 49.68’W.

We continued through a sunlit landscape of frost smoke until at 1519 we crossed an ice edge into heavy pack ice which looked dramatic in the sunshine. We soon emerged – it was a classic ice edge band produced by an off-ice wind. This was at 72° 15.01’N, 15° 38.4’W.

By 1700 we were into slightly higher air temperatures (-19.9°C), a lower SST (back to freezing point on bridge sensor) and there was frazil ice everywhere again. Clearly we were now out of the coastal upwelling zone and back into the East Greenland Current proper. At 1730 we did an ice lift, yielding a plethora of young thin well-formed pancakes, from which we analysed pancakes 59-62. We also did a frazil and a stick throw. Our position by 1800 was 72°22.5’N, 15°08.1’W.

We stopped again for an ice lift at 1840, at 72° 21.04’N, 15° 04.39’W, getting lots more new pancakes.

Our intended CTD station location was 72° 30’N, 15° W. We could not reach this because of heavy ice to the north, so stopped at the correct longitude and did the station at 72° 19.6’N, 14° 57.6’W. We then carried on NE towards the next station.

February 26

An error now occurred on the part of the ship. At 0030 we approached the next CTD station, at least the longitude for it (because of ice conditions we had been stopping at the correct longitude for each station without necessarily attaining the correct latitude). We did an ice lift, but then went straight on as the officer said that there was no CTD station. The ice lift yielded pancakes which took us up to no. 88.

Finally we came onto the next station at 72° 24.2’N, 13° 40.65’W (nominally 72° 30’N) at 0430. We continued NE through a continuing alternation of open water and dense pack ice bands. At 0815 we did another ice lift, yielding a huge pancake 70 cm thick which was actually another fringe built around a brash ice core. At 0915 we tried another lift in an ice band but found no pancakes at all, only brash lumps. It looked as if these bands are basically melting, with only debris of collisions between the floes, not newly forming young ice.

At 0930 a CTD started at 72° 28’N, 13°W. It was over in only an hour as the water depth was only 1100 m, a northerly spur from the Jan Mayen Fracture Zone. During the station a pair of seals could be seen on a nearby ice floe. The CTD was followed by an ice lift which produced one large and one smaller pancake, both of which may have had the composite structure of a pancake built on brash.

At 1220 we stopped for a CTD at a location which was short of the intended site but which was near a good sharp ice edge, suitable for the AUV test which was to come next. The CTD was done at 72° 36.4’N, 12° 33.5’W. Bo had said that the AUV should be ready for testing by 1300, but a succession of new bugs was discovered. With the CTD over, we stood by waiting for the AUV availability. Eventually, about 5, it was clear that the AUV could not be ready this day. In fact Bo said that the fault could take 12 hours to fix, involving removing the main pressure vessel and changing components inside it. We set up a programme of

CTDs that would take us NE and N, and thus nearer to the chimney, while permitting us to stay in the ice in case the AUV could be ready the next day. Then we would either stay in the area or head onwards, depending on AUV availability.

At 2005 we reached the next CTD station, at 72° 40.1'N 12° 09.9'W. This was also quite fast and finished before 2200. We resumed heading NE. This area is not good for pancakes, although we did try lifts and processed a few pseudopancakes that were really brash. In effect we were in a set of ice bands, created by the off-ice wind which had been blowing that last couple of days. The pack, whose outer fringe of pancakes had been swept away or swept downstream by the great broom of the recent storms, expanded outwards again when the wind changed to W, but did so by opening into bands. Pancake formation does not take place between or within the bands because the water seems to be above freezing point, whether it is because of erosion of the thermocline by wind-induced wave action, upwelling, or just our easterly longitude relative to the core of the East Greenland Current. At any rate, within the bands the only small pieces of ice are solid lumps of brash.

We tried mapping the bands for a couple of hours, noting that the floes that they contain look completely beaten-up, with brash fragments rafted over their tops, showing the violent action of the recent storm. Bo solved the AUV problem during the evening and said that the AUV would be ready at first light.

February 27 – AUV Experiment

This was our most successful day in the ice.

During the night we did a CTD station at 72° 50'N, 11° 30'W, about 0100-0200. Then we steamed due N to another station at 73° N, 11° 30'W, which put us close to one of the E-W lines that we did when we first entered the ice. This started at 0500, at which time conditions looked unusually good. The air temperature was up to –12.5° C, and the wind was down to 22 kts, coming from the W and thus generating no swell. This was the first time we had experienced both warmth and calm.

The CTD came up at 0650 and we started to head the ship W, looking for a site for the AUV for first light. It was clear, however, that there was plenty of ice at this longitude, so we headed N instead, and after only half an hour found a suitable ice band, about 1/2 mile wide, with dense pack ice inside and sharp edges. We decided that we would stop here and wait for daylight, so as to give the AUV every opportunity to collect data. During breakfast, however, the Mate motored around and discovered that the next band was wider and had a wider range of possible bearings for its edge – it curved round in a sort of bay. We decided to stay at this one, which was at 73° 01.6'N, 11° 39.75'W.

At 0900 it was nearly light with clear conditions. An almost full moon was slowly setting as an even more beautiful sun was rising. We began by mapping a stretch of ice edge, cruising up and down and giving Bo a set of GPS points to enter on his computer. We shifted slightly W to a N-S part of the bay, so that the ice edge would not move in on the AUV during a run (wind was from the N now, giving a SW wind drift to add to the southward current set). Then, at 0950 the AUV was launched successfully. The ship refrained from blasting it with a thruster; instead it was allowed to move away from the ship under its own power while we gently backed away using only the screw.

Preliminary trials comprised, first a N-S line on the surface then a dived run at 10 m depth. Finally, at 1145 Bo was happy and prepared the first data-gathering run, a run along a 225° line for 700 m in, turning and doing a line out 30 m away. Vehicle depth was 20 m, and speed 1.2 m/s. He had to wait for a GPS fix update, then at 1240 the line was launched. The craft submerged near the ice edge and was gone. Half an hour later it popped up only 200 m from its planned position. It transmitted its data to the ship, and Bo displayed it before trying the next run.

A very clear sidescan sonar record appeared, of only 40 m range to each side (hence half the field taken up by travel time) but showing floes, waves and brash very clearly. The inner line, from the lobe pointing nearly vertical, showed the draft of the floes. There was some minor electrical interference, perhaps from the flashing light electronics.

The next run was planned for a course of 270°, and would be a 1000 m run with 80 m spacing between the in and out courses, at a depth of 10 m (to improve the sidescan record) and a speed of 1.2 m/s. The run was started at 1405. We stayed in the same place, but planned for the next run to follow the AUV into the ice so as to film the same ice floes from the top.

About 40 minutes later she sent a signal showing that she had surfaced, but could not be seen. What had happened was that the ice edge had become more diffuse during the day, with floes breaking free from the formerly sharp edge and forming a zone where the chances of encountering a floe at random were quite high. The AUV with her low profile and with only a small antenna as a target to spot, seemed to be lost behind a floe. We went cruising around looking for her. Using a DF antenna we got some fixes which enabled us to zero in on the vehicle, finding it safely surfaced but up against an ice floe. Bo reckoned that he did not have enough battery power for another run, so the vehicle was recovered with the aid of the Zodiac. This run yielded 2 km of further excellent sidescan data.

The plan now was after all to follow the track of the AUV into the ice, as this had been the last run. The digital video system was set up in the crow's nest pointing forward. There was then a wait while the sonar tracking system was hauled up, as the crane wire broke. We started the run at 1635. After 1 km the Captain did a Williamson turn and brought us back out along the same line.

The final task of this successful day's operations was to enable Claus to dive under ice, and, by filming and examining the under surface of the floes enable us to correlate their structure with the sidescan backscatter. He went out in the Zodiac with Edmond, they pulled themselves up onto a floe, and then he dived under the floe.

The boat was back at 1745 and then at 1757 we bade farewell to this scene and set off for the convection cell. It would have been fruitful to stay another day, but the fact that "Aranda" had done only 2 stations and not found the chimney meant that the entire task of finding and resurveying this chimney fell on us. As it was the most scientifically important part of the cruise, we could not feel justified in adding another day to the ice programme.

On the way out of the ice, bands of ice were still everywhere, and then at 1900 we ran into an immense field of pancakes. They were quite thin but big and strong, obviously formed since the last storm (so we might be able to date them). We did two hauls and pulled in about 15, including some perfectly shaped ones that just fitted inside the lifter. This meant that the rest of the evening was set to be spent processing them, so that the work would be done before we emerged into the (presumed rough) open sea.

We were on the lookout for more pancakes further along, but in fact this seemed to be an isolated case of freezing water, and elsewhere it was back to large expanses of completely open water, with bands of dense ice in which the floes were wave-battered and the only smaller pieces were lumps of brash rather than pancakes. We plotted most bands as we went through them . Visibility was superb because of a completely full moon.

In the end the pancake count reached 113. This last set of pancakes is valuable, because they were clearly all formed together, so differences in salinity will show the real variability that occurs in the way these ice types form under identical conditions.

Phase 3: Resurvey of deep convection cell

February 28

Our route to the NE kept us in ice bands until about 0300. We had slightly adjusted our track to bring us back over Barry Uscinski's sites on Vesterisbanken, to record ice conditions there. The mix now consisted of nearly all water and only a few bands, mostly just a couple of floes wide, but it was remarkable to see how floes tend to form coherent bands. But there were also an increasing number of isolated floes – perhaps from bands that had decayed. We passed over the Uscinski sites, at 0140. Minor amounts of ice continued until 0300, which places the outermost ice at the same longitude as when we entered the ice cover at this latitude, although the composition is clearly different.

We spent the day en route to the gyre centre, although we had no idea of the exact location, or even the continued existence, of the chimney. Jürgen Holfort's two stations had been far off to the SE, while our own two stations near the October centre had shown no exceptional depth of convection. I had a feeling that the centre lay in the NW of our 5 x 5 station search grid, for no good reason except a hunch, so I began the search at station 25, the furthest NW, at 74º 59'N, 0º 07'W. To our amazement we hit the centre first time. On the down cast there was uniform water down to 2470 m. The chimney was just as deep as last year, and had moved back to almost its original position after a short southward excursion during the summer. This enormously simplified our task, because all we had to do now was survey it (although this depended on weather), rather than spending precious hours or days searching for it.

My original search grid was a subset of the 25 element, 3 mile spacing grid of the early part of the voyage, missing out every other station to give 6 miles spacing. This was no longer needed, so I drew up a new grid of 8 stations surrounding 25 (which in our numbering system was 2027) at 3 miles spacing.. We saw that during station 2027 we had drifted some 2 nml to the SE, so we asked the bridge to try to minimise drift on future stations. At the same time we took care in recording times at which casts go down and come up, so as to interpolate the drift and arrive at station positions which most accurately reflect our real position at the time of measurement (a slanted representation of a cast in x,y,z space would be ideal of course).

The cast came up just before midnight and we headed at 6 kts (to allow the ADCP to work) for the next station.

March 1

We arrived at our next station, 2028, at 74º 59'N, 0º 05'E, soon after midnight. The CTD went into the water at 0025. Once again there was convection, but only down to 1490 m. This was extraordinary, because due to drift this station was only perhaps 2 miles from the previous one. Such a shallowing of convection implies a very sharp wall to the chimney, much sharper than the one that existed last winter. Somehow the whole structure has tightened up. Below the convection limit the temperature rose to a maximum, as it did in the last station at a much greater depth. This is consistent with what was seen last year, where the chimney "pushed down" the temperature maximum beneath it to a greater depth than the maximum layer around the chimney. At this and the first station we took bottle samples for Gascard (iodine 129) and ourselves (oxygen 18).

The cast came up at 0350 and we moved on to the next station. We came on to station 2029, at 74º 56'N, 0º 05'E, at 0450. Once again convection extended to a moderate depth of 1410 m. As with the last station, we were defining a steep "wall" to the chimney.

Unfortunately weather now intervened. At 0800 we were heading W for the next station, but the sea had come up because of the passage of an unexpected polar low which was not predicted in the previous day's weather forecast. The Captain decreed that CTDs must cease, although conditions looked tenable.

The polar low made its vicious way out of the Barents Sea to dissipate in a mysterious way over the north coast of Norway. It kicked up a heavy, steep, short sea which we had to endure for the rest of the day.

March 2

The sea went down overnight and we headed for our next station position. This was station 3 in our close-in survey plan, now numbered 2030, at a nominal position of 74º 56'N, 0º 07'W. We started the station at 0820 but experienced two successive problems. Firstly, the winch was not layering the wire properly and had to be fixed, which entailed freeing it from its coating of solid ice and tinkering inside the gear box. Next all electrical connections were lost between the CTD and the deck unit, due to a wire coming adrift; plastic insulation had been used, which becomes brittle in extreme cold. Finally we started properly at 1010.

Convection went to the exceptional depth of 2390 m. This station is 3 nml due south of the original "nail-on-the-head" station which had 2470 m of convection, so clearly we were still close to the chimney centre. Just below the convective limit the temperature rose rapidly to the "pushed down maximum" so characteristic of the cell. In this case there was also a smaller maximum in the temperature profile within the cell, at about 1400 m depth. This is a mystery, as is the whole question of this T_{max} layer, the reason for its existence, and the reason for its downward displacement by the chimney by some 1000 m.

The CTD reached surface at 1230 and we sailed at 6 kts (so as to run the ADCP) to station 4, numbered 2031, at nominal position 74º 56'N, 0º 19'W, 3 nml west of station 3. We reached this at 1320. By now the sea had really gone down to a remarkably calm state with almost no wind. At this station we put a current meter on the bottom of the CTD frame and stopped at seven depths for 10 minute runs during the station, adding more than an hour to its duration but permitting the currents in the cell to be determined in the absence of moorings (which cannot be put out for lack of time).

At this station convection reached 2300 m. Interestingly, the temperature was significantly colder at each depth inside the cell than for the previous station, and the salinity slightly higher, indicating that there is an internal structure to the chimney – not all the water in it has exactly the same properties, and there is lateral variability. Possibly this relates to lateral heat or water exchange with the outside. Once again there was the sub-cell T_{max} but no other temperature maxima within the cell, although a lot of fluctuations within the uppermost 200 m and at about 600 m.

Currents were measured at 3500, 2500, 2000, 1500, 1000, 500 and 100 m, and after this lengthy process the CTD came out at 1738, after more than 4 hours, and we started for station 5. Edmond had run the ADCP and got a rough-and-ready near-surface current reading of 10-20 cm/s towards W and the same towards N. This is what we would expect from a location SW of the cell centre if the rotation is anticyclonic.

At about this time we received a Radarsat image which had been ordered to replace the one which unaccountably failed to be taken. This showed the band structure of the ice edge region in superb detail – although unfortunately more than 2 days late as far as direct ground truth is concerned.

Station 5, numbered 2032, was reached at 1823. The nominal position was 74º 59'N, 0º 19'W. There was once again a problem with the electrical connection between CTD and computer, and it was 1915 before the cast began. Convection depth was 2055 m. We had now moved 3 nml north, and were on the west side of the chimney centre. The temperatures showed instabilities down to 900 m, where there was a small T_{max}. Again the main T_{max} lay beneath the cell, while both salinity and density rose at the cell bottom in two gentle but distinct steps. The near-surface water was the coldest yet, dropping below –1 C at 400 m, but it converged on the temperatures elsewhere in the chimney below 1500 m.

The CTD came out of the water at 2145 and we moved on to station 6, numbered 2033, which we reached at 2225. Nominal position was 75º 02'N, 0º 19'W, the NW corner of the survey grid. Here the convection depth was only 1660 m. The two gentle steps seen in the previous station's salinity and density below the cell turned in this case into two quite large steps. At the same time the temperature structure was very weird. At the surface, and down to 400 m, there was a warm layer (about –0.883 C) which suddenly dropped at 400 m down to –0.915 C in a step. This layer had lower salinity and density (28.052), with the step taking the density back to the "normal" chimney value of 28.056. Presumably there is an intrusion from a neighbouring near-surface water layer. Beneath the cell, where the salinity and density steps were, the temperature profile rose abruptly then looped back suddenly to a low value, then up again to a T_{max}.

March 3

The CTD came up at 0125 and we moved on to station 2034 (station 7 of survey), at 75º 02'N, 0º 12'W, in the middle north of the survey area. Because of bad layering of the wire the CTD received a jolt going into the water, and for a while we thought that the salinity sensor had broken, but it seemed to cure itself so we proceeded.

Once again there was a warm layer at the surface, 400 m thick, with T actually rising as we descended, to a peak of –0.8396 C, before jolting back quite suddenly to –0.9182 C. Salinity stayed steady, but density was thus lower in the surface layer. The origin of this water is a mystery, but it is undoubtedly the same intrusion as in the previous station. Convection depth here was 1710 m, and the temperature then rose to a T_{max} at 2024 m, of –0.7354 C, along with single large steps of salinity and density. This maximum changed its structure on the way up, implying that we were drifting. In fact the wind was now starting to come up, an ominous sign.

At 0700 we started station 2035 (station 8 of survey), at 75º 02'N, 0º 05'E, the northeast corner of the grid. Once again the current meter was mounted, to get a profile on the opposite side of the cell centre from the previous one (current directions should be reversed). The depth of convection here was 1484 m, and the structure of the profiles was quite simple except for a double bump at the T_{max} level. As soon as this limit had been found, the 9 stations done so far were run through a contouring program for convection depth, to identify the location of the centre of the cell, where we wanted to go next (to do a CTD and deploy the APEX float. The centre derived from the calculations without allowing for drift was 74º 58'N, 0º 09'W.

Unfortunately the station was very slow because of the current meter and the CTD was not on deck until 1136. By then things looked bad. The wind was up in the 20s of kts, and soon rose beyond 30. The sea was at first not too bad, but as we steamed for the "centre station" it grew before our eyes under the strong wind. We could not proceed with the station and were forced to stand by helplessly for the rest of the day while the wind and sea grew.

March 4-8

The sea stayed high all day on the 4^{th} and then rose in the evening to a severe storm with winds above 40 kts and some giant waves. The Captain left the chimney position in the morning of the 5^{th} because of potential icing conditions and moved 70 nml south, from which we slowly moved back during the morning of the 6^{th}.

We came back onto position at the location which we had determined to be the centre of the chimney (74° 58'N, 0° 09'W) at noon, moved the ship 1 nml upwind, and then deployed our APEX float. This remains on the surface to complete an initial six hour cycle (we had switched it on two hours before deployment) then sinks to 1000 m park depth. The drift allowance is such that we hope that it sank at the chimney centre. Every 10 days it sinks further to 2000 m then profiles upwards to the surface and transmits salinity and temperature data before sinking to park depth again.

This turned out to be the last piece of scientific work done on the cruise. We moved back to the position of the one station needed to close off the chimney contours to the south. The wind was too high and the sea too rough to do a CTD. In principle we could have waited here until at least the night of the 7th for the sea to go down, and still reach Tromsø by noon on the 10th, the official end of the cruise. In practice, on the basis of weather forecasts of no improvement, the Captain chose to leave the location at 1700 on the 6th and head directly to Tromsø, where we arrived early on the morning of March 9.

Hydrographic structure

Narrative

The responsible scientists in the CTD team were Vladimir Pavlov, Edmond Hansen, Terje Løyning and Kristen Fossan. A Seabird 911+ CTD was used, with a double set of sensor packages. Both primary and secondary packages had been calibrated before the *Lance* CONVECTION 2002 cruise. The primary package was used whilst the second was removed, do to the harsh conditions, approximately halfway through the cruise and kept as a replacement. The CTD was equipped with a rosette with twelve bottles, electronically controlled from the deck unit. The bottles were used for taking salinity samples, 0^{18} and I^{129} sampling. Salinity samples were taken at most stations. The salinity samples will be analysed with a high precision salinometer, and the results will be used to adjust the salinities measured by the *Lance* CTD.

Seabird's standard Windows based software was used for logging (SEASAVE for Win95/NT) and post processing (SEASOFT – SBE data processing) of the data. The standard procedure for pumped SBE911 data processing as recommended by SBE was followed (cf. SBE SEASOFT manual). The following table lists the position, date, time and depth of the CTD stations made during the cruise.

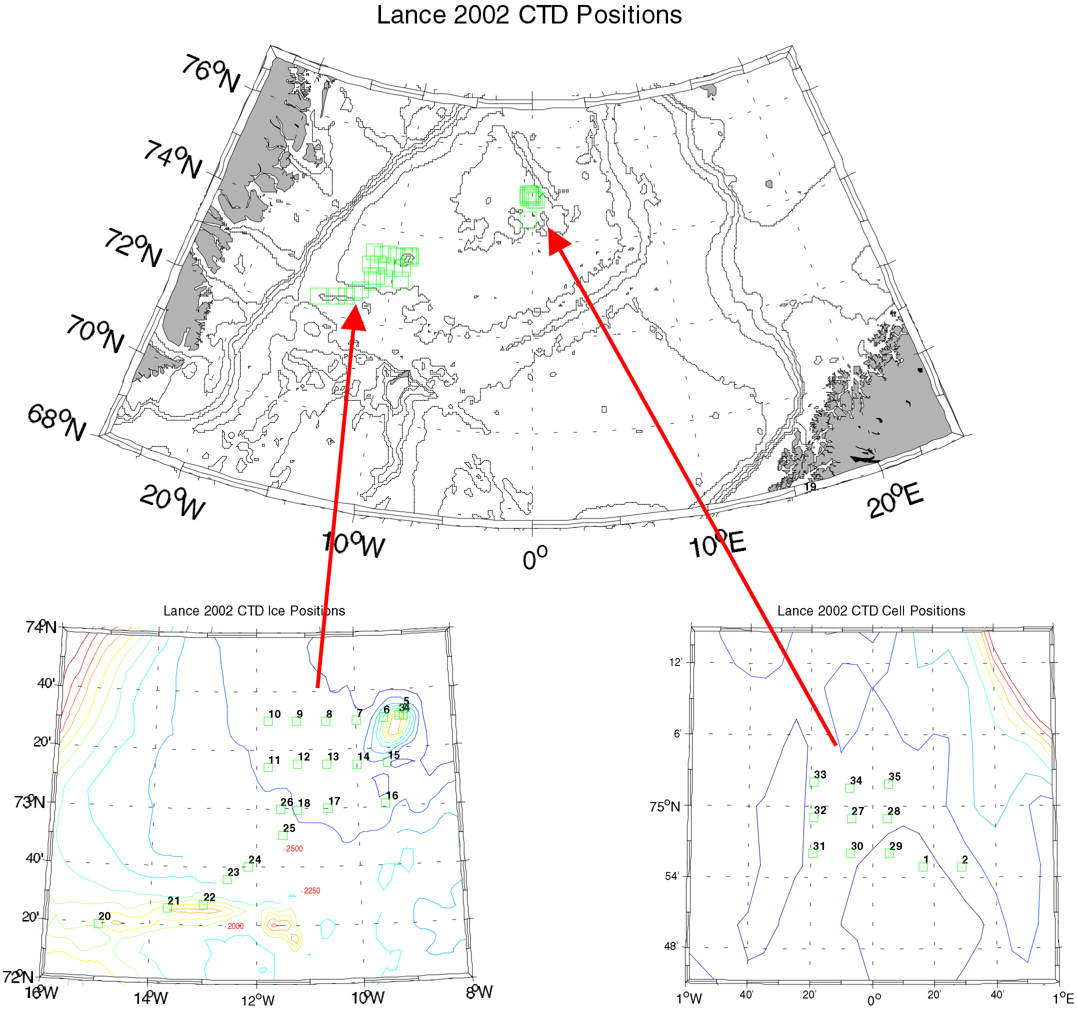
CTD station positions

St.	Date	Lat.	Long.	Pres.	Temp	Cond.	Salt	I-129	O-18	Salt
001*	2002.02.17	74 54.9N	00 16.4E	4	-0.9197	2.8156	34.870	8	8	
-	-	-	-	106	-0.6904	2.8414	34.880	7	7	
-	-	-	-	197	-0.8061	2.8348	34.882	6	6	2
-	-	-	-	493	-0.7880	2.8505	34.889	5	5	
-	-	-	-	1480	-0.8360	2.8901	34.893	3	3	
002	2002.02.17	74 54.9N	00 29.0E	101	-0.8443	2.8275	34.887	13	27	14
-	-	-	-	195	-0.8150	2.8347	34.890	11	23	
-	-	-	-	497	-0.7914	2.8506	34.891	12	22	
-	-	-	-	988	-0.8671	2.8655	34.884	10	18	
-	-	-	-	1992	-0.8182	2.9139	34.914	1	4	9
003	2002.02.19	73 30.9N	09 07.1W	46	-1.7491	2.7366	34714		1	
-	-	-	-	100	-1.3860	2.7716	34.745		2	
-	-	-	-	295	0.2430	2.9304	34.904		13	
-	-	-	-	500-	-0.1689	2.9050	34.906		12	4
004	2002.02.19	73 30.8N	09 02.8W	99	-1.7782	2.7370	34.724		9	16
-	-	-	-	294	0.4072	2.9459	34.915		11	
-	-	-	-	492	-0.1991	2.9022	34.907		10	15
005	2002.02.19	73 33.1N	09 02.2W	48	-1.7866	2.7312	34.685		17	
-	-	-	-	100	-0.9792	2.8063	34.752		20	18
-	-	-	-	294	0.4418	2.9487	34.918		14	
-	-	-	-	497	-0.1655	2.9054	34.909		15	17
006	2002.02.19	73 30.5N	09 26.8W	1001	-0.8095	2.8713	34.889			20
-	-	-	-	2167	-0.8847	2.9154	34.915			19
007	2002.02.19	73 29.8N	10 00.0W	1500	-0.7322	2.9009	34.911	17	33	22
-	-	-	-	1997	-0.8396	2.9125	34.915	16	32	
-	-	-	-	2497	-0.8888	2.9282	34.915	15	21	21

St.	Date	Lat.	Long.	Pres.	Temp	Cond.	Salt	I-129	O-18	Salt
008	2002.02.20	73 29.8N	10 36.7W	4	-1.6300	2.9365	34.619	25	24	
-	-	-	-	99	0.4699	2.0952	34.823	24	31	
-	-	-	-	196	1.1699	3.0144	34.921	23	55	
-	-	-	-	498	0.0337	2.9230	34.913	22	40	
-	-	-	-	999	-0.7379	2.8774	34.891	21	39	24
-	-	-	-	1497	-0.7120	2.9024	34.911	20	30	
-	-	-	-	1998	-0.8390	2.9127	34.915	19	38	
-	-	-	-	2500	-0.8883	2.9290	34.915	18	39	23
009	2002.02.20	73 30.0N	11 11.0W	847	-0.3338	2.9064	34.907			26
-	-	-	-	2784	-0.8816	2.9398	34.913			25
010-a	2002.02.20	73 30.0N	11 45.0W	94	-0.7838	2.7229	34.537	29	34	
-	-	-	-	201	1.1254	2.0036	34.918	28	29	28
-	-	-	-	496	0.0919	2.9276	34.910	27	28	
-	-	-	-	1011	-0.6799	2.8832	34.895	26	16	27
011	2002.02.20	73 14.3N	11 46.3W							
012	2002.02.20	73 15.0N	11 11.2W	498	-0.0029	2.9196	34.912			30
-	-	-	-	2760	-0.8411	2.9381	34.913			29
013	2002.02.20	73 14.8N	10 35.6W	498	0.0295	2.9224	34.912			32
-	-	-	-	1998	-0.8549	2.9113	34.915			31
014	2002.02.21	73 14.8N	09 59.7W	496	-0.0599	2.9147	34.913			34
-	-	-	-	1975	-0.8426	2.9113	34.914			33
015	2002.02.21	73 15.0N	09 24.0W	497	-0.1825	2.8819	34.617			36
-	-	-	-	2.959	-0.9157	2.9442	34.921			35
016	2002.02.21	73 01.0N	09 28.0W	1997	-0.8503	2.9113	34.912			37
017	2002.02.21	73 00.0N	10 36.0W	2630	-0.8951	2.9326	34.911			38
018	2002.02.22	72 59.5N	11 11.3W							
019	2002.02.24	74 29.7N	00 15.4W	1675	-0.6933	2.9094	34919			39
020	2002.02.25	72 19.6N	14 57.5W	1887	-0.8201	2.9096	34.914			40
021	2002.26.02	72 25.6N	13 40.2W							
022	2002.02.26	72 27.0N	13 00.0W	1041	-0.5840	2.8920	34.896			41
023	2002.02.26	72 35.8N	12 32.9W							
024	2002.02.26	72 40.0N	12 09.0W	2008	-0.8527	2.9116	34.911			42
025	2002.02.26	72 50.7N	11 29.3W	2505	-09044	2.9268	34909			43
026	2002.02.27	72.59.8N	11 30.9W	2502	-0.8820	2.9287	34.911			44
027	2002.02.28	74 59.0N	00 06.5W	98	-0.9826	2.8154	34.881	37	88	
-	-	-	-	200	-0.9745	2.8203	34.881	36	87	
-	-	-	-	501	-0.9698	2.8348	34.880	35	86	
-	-	-	-	999	-0.9452	2.8591	34.881	34	85	
-	-	-	-	1497	-0.9220	2.8825	34881	33	84	
-	-	-	-	2000	-0.9395	2.9014	34.878	32	83	
-	-	-	-	2496	-0.8057	2.9340	34847	31	829	
-	-	-	-	2997	-0.8475	2.9506	34.909	30	81	45
028	2002.02.28	74.59.0N	00 05.1E	3	-09720	2.8119	34.882	46	97	
-	-	-	-	96	-1.9383	2.8191	34.882	45	96	
-	-	-	-	199	-0.9352	2.8241	34.882	44	95	
-	-	-	-	502	-0.9155	2.8395	34.881	43	94	
-	-	-	-	999	-0.8971	2.8631	34.881	42	93	46
-	-	-	-	1497	-0.8557	2.8885	34.887	41	92	
-	-	-	-	1998	-0.7688	2.9181	34.907	40	91	
-	-	-	-	2499	-0.8432	2.9317	34.910	39	90	
-	-	-	-	3550	-0.8966	2.9663	34.903	38	89	

St.	Date	Lat.	Long.	Pres.	Temp	Cond.	Salt	I-129	O-18	Salt
029	2002.03.01	74.56.0N	00 05.6E	100	-0.9446	2.81.87	34.881	53	99	
-	-	-	-	200	-0.9418	2.8235	34.881	52	98	
-	-	-	-	499	-0.9944	2.8387	34.881	51	104	
-	-	-	-	996	-0.9088	2.8620	34.880	50	103	
-	-	-	-	1499	-0.8156	2.8923	34.812	49	102	
-	-	-	-	1996	-0.7764	2.9174	34.908	48	101	
-	-	-	-	2498	-0.8472	2.9314	34.910	47	100	47
030	2002.03.02	74.56.0N	00 07.0W	101	-0.9806	2.8158	34.881	61	112	
-	-	-	-	200	-0.9810	2.8202	34.881	60	111	
-	-	-	-	500	-0.9681	2.8349	34.881	59	110	
-	-	-	-	995	-0.9464	2.8588	34.881	59	109	48
-	-	-	-	1496	-0.9397	2.8806	34.880	57	108	
-	-	-	-	2000	-0.9463	2.9008	34.877	56	107	
-	-	-	-	2497	-0.8403	2.9307	34.843	55	106	
-	-	-	-	3000	-0.8581	2.9497	34.909	54	105	
031	2002.03.02	74 56.0N	00 19.3W	4	-0.9942	2.8102	34.884	70	43	
-	-	-	-	97	-0.9698	2.8165	34.883	69	42	
-	-	-	-	195	-0.9645	2.8216	34.884	68	41	
-	-	-	-	500	-0.9527	2.8365	34.884	67	118	
-	-	-	-	1002	-0.9452	2.8593	34.883	66	117	49
-	-	-	-	1494	-0.9156	2.8793	34.881	65	116	
-	-	-	-	1998	-0.9470	2.9008	34.880	64	..115	
-	-	-	-	2492	-0.8323	2.9305	34.897	63	114	
-	-	-	-	3503	-0.8877	2.9656	34.907	62	..113	
032	2002.03.02	74 59.0N	00 19.0W	100	-0.9855	2.8154	34.883	75	48	
-	-	-	-	202	-0.9872	2.8199	34.883	74	47	
-	-	-	-	499	-1.0119	2.8311	34.880	73	46	
-	-	-	-	1000	0.9968	2.8547	34.881	72	45	
-	-	-	-	2000	-0.9417	2.9014	34.880	71	44	50
033	2002.03.02	75 02.0N	00 19.1W	5	-0.9170	2.8166	34.881	84	57	
-	-	-	-	104	-0.9093	2.8218	34.881	83	56	
-	-	-	-	205	-0.9064	2.8268	34.882	82	55	
-	-	-	-	503	-0.9231	2.8391	34.882	81	54	
-	-	-	-	1005	-0.9258	2.0611	34.883	80	53	51
-	-	-	-	1500	-0.9155	2.8831	34.884	79	52	
-	-	-	-	1998	-0.7470	2.9201	34.911	78	51	
-	-	-	-	2500	-0.8845	2.9319	34.912	77	50	
-	-	-	-	2998	-0.8859	2.9473	34.911	76	49	
034	2002.03.03	75 01.5N	00 07.2W	202	-0.9775	2.8205	34.881	90	64	
-	-	-	-	502	-0.9783	2.8343	34.883	89	62	
-	-	-	-	1001	-0.9576	2.8582	34.882	88	61	
-	-	-	-	1505	-0.9401	2.8812	34.882	87	60	
-	-	-	-	1958	-0.8890	2.9008	34.888	86	59	
-	-	-	-	2501	-8252	2.9337	34.913	85	58	52
035	2002.03.03	75 01.9	00 05.2E	2507	-0.9020	2.9645	34.907			53

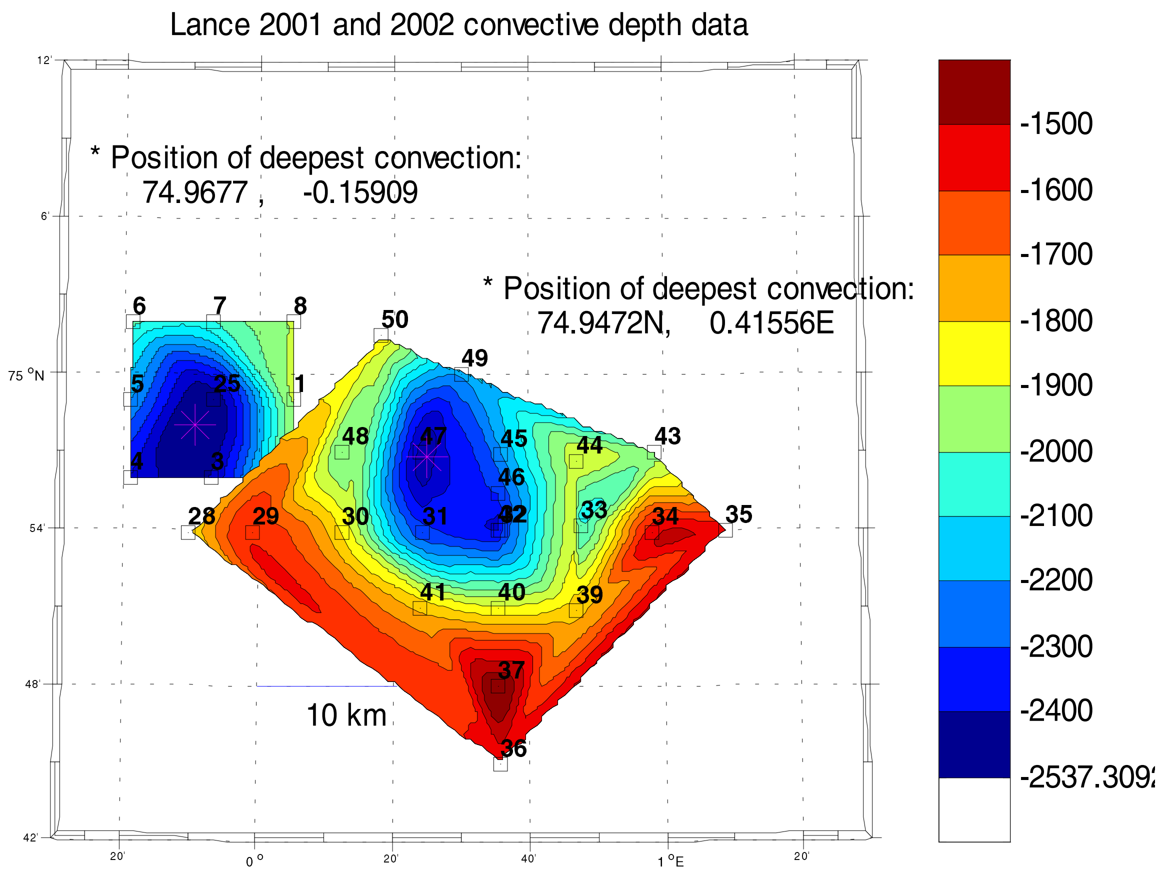
*- File with row data was damaged



CTD Positions

Convective cell

The convection that occurred this year was the deepest in 30 years. By optimising the time available for the cruise we were able to study the convective cell in detail. CTD stations were performed both before the ice work as well as after. A basic contour plot of the cell can be seen below with respect to the cell from last year's survey.



Convection depths of the chimney. Last year's survey (larger picture), this survey (smaller picture).

APEX Float

An APEX park and profile float was released slightly north of the centre of the chimney in order to monitor the Chimney's T and S structure from 2000 m to surface once every 10 days.

The float was removed from its crate and placed horizontally on the foam cradles. The protective bag and plugs from *Seabird* sensor were then removed. At ~10 am on 6 March the float was reset for deployment by placing the magnet stationary for several seconds on the hull on top of *reset* sticker. The magnet was then removed and the start sequence began.

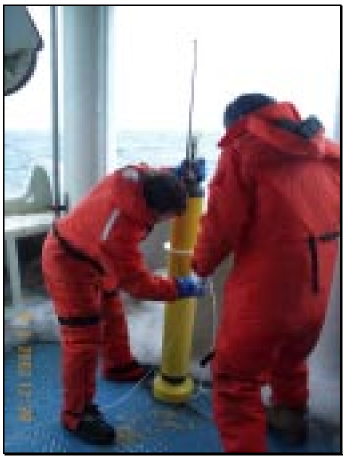
The start sequence is performed automatically as follows:

- 3 seconds after magnet is removed the air pump will run for one second.
- 6 Argos transmissions in 6 second intervals will be transmitted – This was confirmed by holding the transmission detector next to antenna.
- 10-20 minutes will pass while oil bladder fully inflates.
- once the oil bladder is fully inflated the float will transmit every 44 seconds for the remainder of 6 hour test message sequence. Until the air bladder is

fully inflated each transmission will be accompanied by the air pump running for six seconds . It is during this period we confirmed the air bladder was inflating by removing black plug from base of float. It will take several transmission/air pump cycles to fully inflate bladder. It is important that the black plug is reinserted before the bladder is fully inflated.

The float passed the start sequence successfully and the black plug was reinserted. The float was now read for deployment. As the float makes its first descent 6 hours after reset (and it is important that the float be put in the water before the six hour test message sequence expires) we decided to wait 2 hours before deploying the float, the reason being that we did not want the float to be blown out of the area of the convective cell (wind blowing ~40 kts at the time). We came back onto position at the location which we had determined to be the centre of the chimney (74° 58’N, 0° 09’W) at noon, moved the ship 1 nml upwind and then deployed the float.

Seabird sensor on float



Launching float

After sinking the APEX float parks at 1000m, just before it is set to profile the water column it sinks to 2000m, its profile depth. Once it reaches its profile depth it profiles the water column at specified depths until it reaches the surface. Once on the surface it send its profile message at 45 sec intervals (15 messages makes one profile) and sinks ~6 hours later and the process starts again. In this set-up the float should last 3 years.

The specifications of the float are as follows:

Depth table no. 26

Timing:
Down: 229 hours
Up: 11 hours
TOTAL cycle (Down + Up): 10 days

ARGOS Multi-satellite service used?
YES

ARGOS repetition rate 45s

Latitude: **75N**

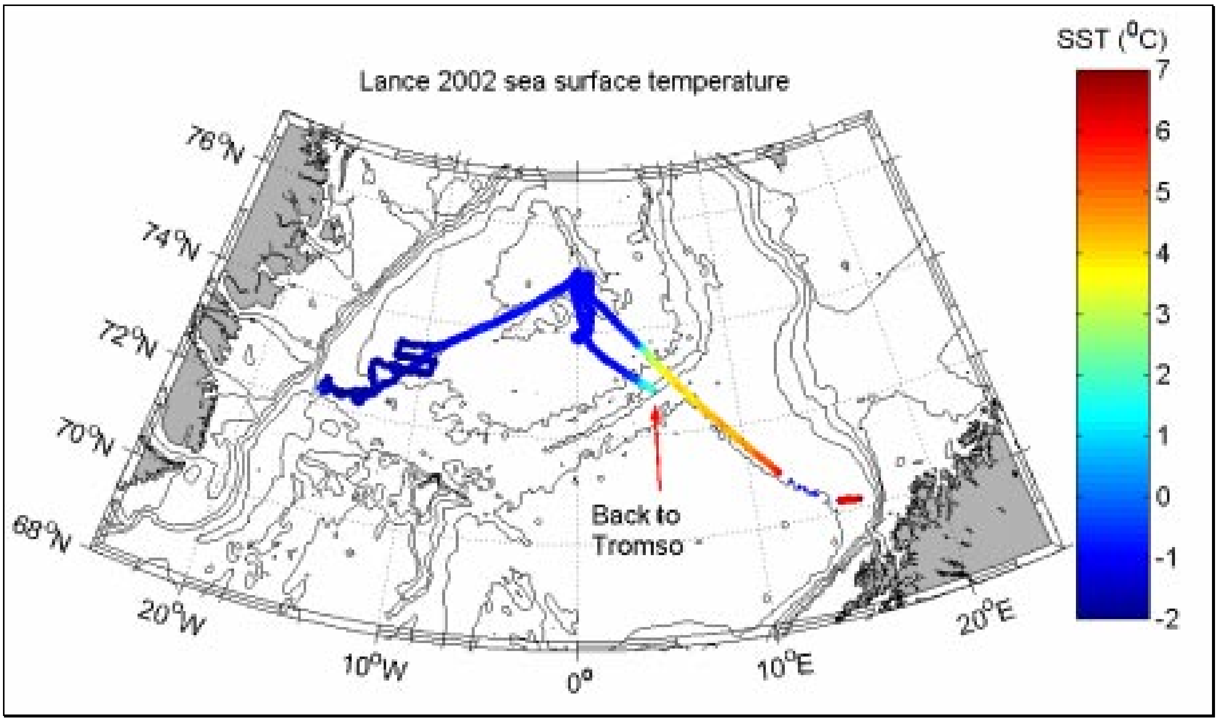
Ballasting:
PARK AT:
P: 1000 db
T: -0.85 C
S: 34.885
: 1.03280

PROFILE TO:
P: 2000 db
T: -0.99 C
S: 34.9068
density: 1.037458

Environmental parameters

The hourly meteorological observations were designed to be analysed to as to yield ocean-atmosphere heat fluxes from bulk formulae. For this report the data has been processed into daily meteorological report sheets covering the period from 15 February 2002 through to 8 March 2002. Each report sheet is divided into the following meteorological parameters, from top to bottom:

1. Sea surface temperature
Sea surface temperature was recorded by a sensor located approximately 3 m below sea level. Sea surface temperatures are a good indicator of the spread of the different water masses in the region. For example the plot below shows the colour coded SSTs during the cruise. To the east lies the warm water of Atlantic origin, whilst to the west are the cold Polar Waters of the east Greenland Current. The central region contains a complex mixture of these two water masses as well as water has undergone convection in previous winters.



2. Wind speed and direction
Wind speed in knots, but later changed to m/s, as well as wind direction, in degrees from true to north were recorded. Both readings were derived from a Vaisala WAD 215 and were originally relative to the bow of the ship before being corrected using speed and direction information from the GPS (Raytheon Raystar 920 GPS Navigator). One knot is equal to 0.514 metres per second.

3. Air Temperature
Air temperature was measured in degrees Celsius.

4. Humidity
Humidity was measured as a percentage and was derived from a Lambrecht 50-30-50 sensor system.

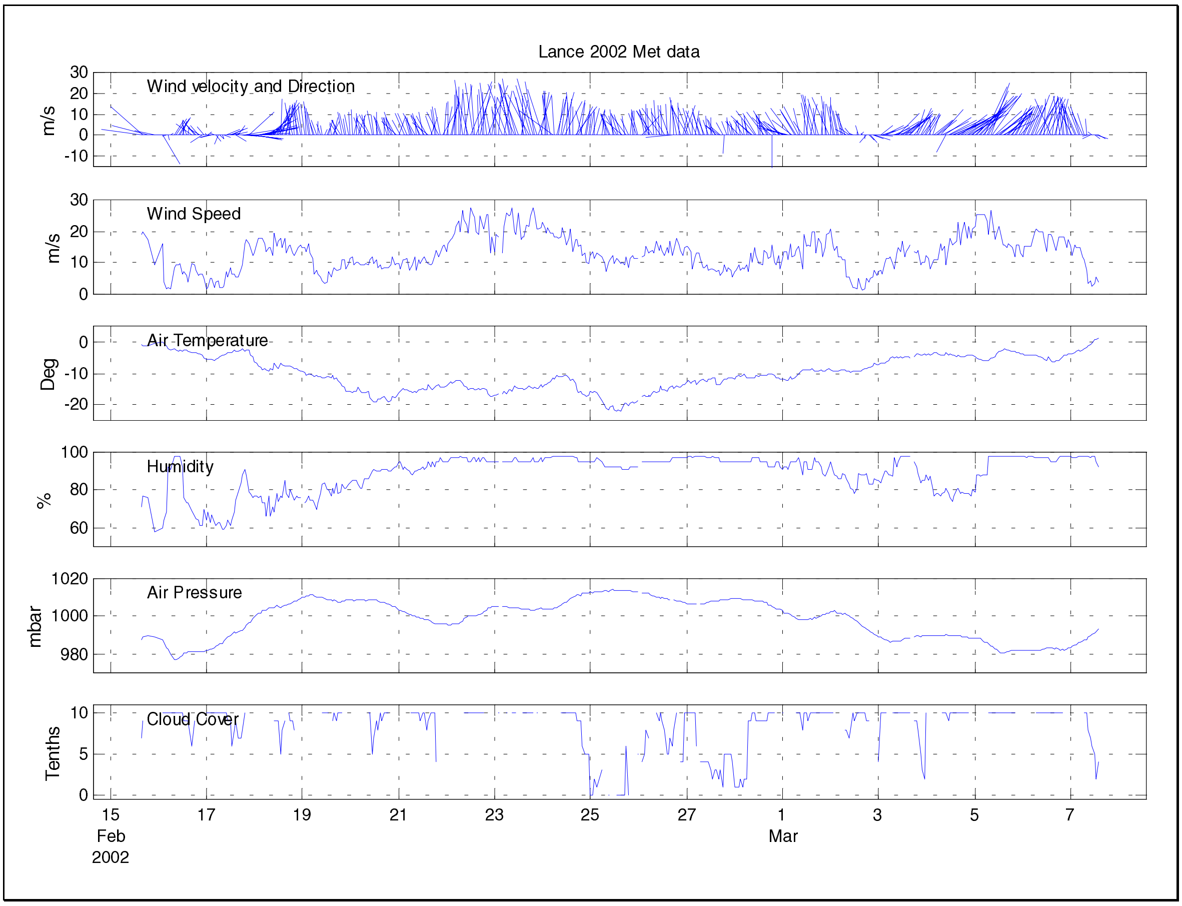
5. Barometric pressure

The air pressure was measured in millibars. The readings were derived from a Vaisala pressure transmitter (Type PTB220AAA2A1).

6. Cloud cover

Measured in tenths as seen from the bridge.

The figure below is a plot of the above mentioned meteorological observations. One can see from this plot that the weather during this cruise was, in a word, *terrible*.



Ocean-Ice Processes

Ice Stations

Whenever the ship was in ice and the weather conditions appropriate an ice station was performed. These stations followed a set routine as follows.

Pancake recovery

At every ice station a number of pancakes were lifted from the ocean's surface using a specially designed ice lifter (see figures below). The *Pancake Ice Lifter* is the workhorse for the ice physics programme. The lifter was designed by SPRI using their knowledge and experience of ice conditions within a pancake sea ice zone in winter. The dimensions of the lifter are 1.5m x 1.5m x 0.5m and it can lift over 2000 kg of ice at any one time. The lifter incorporated a number of novel features to enable a safe, efficient and reliable process for recovering ice from the surface of the ocean, in almost pristine condition, to the ship's deck for onboard analysis. This is the only feasible way to obtain analytical measurements of pancake or brash ice as it cannot be cored *in-situ* as is the process with larger floes.

Lifting pancake/brash ice onto the deck for detailed analysis could be performed most of the time within the sea ice zone despite bad weather, since the ice damped down the waves and prevented excessive rolling. By the time all ice stations had been completed 113 individual pancakes had been analysed.

Luring the pancake into the catcher

Caught…

Bringing pancake on to the deck for analysis.

A typical station can be described as follows. Firstly the ice lifter was connected to the crane and lowered into the water. If the ice was closely packed or there were large amounts of frazil in the water between floes it took quite a while for the ice lifter to sink, despite the fact that it weighs over 400 kg. Once the lifter has sunk to a depth of a couple of metres the crane operator manoeuvres it under a suitable pancake or pancakes. The lifter was then raised capturing the pancakes. Captured pancakes were brought back on deck for analysis. Depending on their size pancakes were either taken from the lifter to the dissection table or if they were too big to be lifted manually the sides of the lifter were released, so they lay flat with the base of the lifter, and the pancakes were slid out and onto the deck.

Once a lift had been completed the job of logging and analysing each pancake began in earnest. Generally most pancake/brash were of such a size that they could be transported to the dissection table where their dimensions and distinguishing features could be logged and photographed. When this was completed a cross-section 0.05m wide was cut across the pancake's longest axis and its temperature profile (every 0.05m from top to bottom) was recorded. This cross-sectional cut was further dissected into pieces 0.1 m long by 0.05 m deep. Each piece was then placed into a clean bottle, melted and its conductivity measured with the Hanna HI8733 conductivity meter.

Conductivities were adjusted from the 25 degree standard of the conductivity meter to 15 degrees which is the standard for salinity measurements.

Finally the conductivities were transformed to salinities,, in order for the salinity profile of each pancake to be determined, using the following equation (UNESCO 1978):

$$SAL = 0.008 - 0.1692\sqrt{K_{15}} + 25{,}3851K_{15} + 14.0941K_{15}^{3/2} - 7.0261K_{15}^{2} + 2.7081 * K_{15}^{5/2}$$

A final section of the pancake, from top to bottom, was cut from the remaining pancake, bagged and placed in a deep freeze for transportation back to SPRI where crystal fabric and oxygen isotope analysis will be performed. In addition to the pancake/brash and core salinities, a number of snow samples and frazil samples were also melted in order to determine salinities of the melt.

An example of the salinity of a sectioned pancake can bee seen below.

Left: Plan view of pancake 33

Right: Cross section of pancake 33 showing salinity and portion cut for thin section analysis

Other Ice Work

Whilst an ice lift or ice floe station was being performed a number of auxiliary ice measurements were obtained. These included frazil measurements and pancake size distribution.

Frazil measurements: Concentration and thickness measurements were obtained from the side of the ship using a frazilometer. Samples obtained were also used for frazil salinity measurements.

Pancake size distribution: Size distribution of pancakes was obtained by photographing a stick with 0.1 m markings thrown from the side of the ship onto the pancakes. This was performed a number of times at different locations during an ice station.

Results

The dates of the ice work coincided with a period of both new ice formation and older pancakes, thus the pancakes analysed ranged from a few hours to several days, to possibly weeks old. The results from this field work are extremely important as they will lead to a better understanding of pancake ice and its development. Brine drainage rates (i.e. salinity) and thickness measurements will be incorporated into the salt flux model presently being developed at SPRI and DTU.

IceCam

IceCam was mounted in the crow's nest before the *Lance* left Tromsø. Due to the exposed position of the system it was not possible to check on it out at sea and so at the time of writing this report it has not been possible to ascertain how much data has been recorded. Because of limited space in the crow's nest the IceCam was mounted on the open platform towards the stern and was pointing out at 135° from the bow on the starboard side (i.e. 45° away from sternwards) as well as being positioned looking slightly downwards. The following image collection strategy was adopted:

- Standard
  One image taken every 5 minutes.
- Enhanced
  One image every minute between 11:00 and 13:00 UTC. This is to provide good image coverage over the most likely times of satellite overpasses, in particular ERS-2.
- Movie
  Ten images taken in a rapid sequence (0.3 seconds between frames) every 5 minutes. This is to allow testing of possible image enhancement and geo-correction algorithms and was carried out between 13:00 and 14:00 UTC.

This gives a daily total of 504 images with an estimated 11,000 images being collected during the cruise. Approximately 5,000 of these are for when the *Lance* was in the ice.

The IceCam camera attitude sensors were operational. These are two electronic clinometers that record the angles of the *Lance's* pitch and roll and provide valuable data for image geo-correction. The Global Positioning System (GPS) and environmental sensors are currently awaiting repair/upgrade and were non-functional. Ship's log data will be added to the IceCam data during post-processing.

The cruise results will be posted on the IceCam web page at
http://www.spri.cam.ac.uk/people/neh25/IceCam.html
once post-processing is complete.

Portable CTD

One deployment of the SPRI SBE Seacat CTD unit was carried out from the ship.

The CTD data were extracted from the unit and processed using SBE's own SeaSoft programs. The CTD is battery powered, logs data to internal memory at 2Hz and carries its own internal clock. A pump-fed conductivity probe within the CTD carries out measurement of salinity. This has a tendency to become blocked when the CTD passes through frazil.

Ice Watch

A record of the ice conditions is an important part of the data collected. This allows the existing database to be added to previous records to be compared, mainly for identifying climatological variations. With the advent of satellite imagery, the ice log provides valuable ground truth data. This is especially important for remote polar regions like the Greenland Sea.

The Ice Watch provides an hourly record (in daylight hours) of the human-interpreted ice conditions, along with the latitude, longitude (from the ships GPS), ship speed (from the ships log), air temperature, air pressure, wind speed, and wind direction (all from the Seatex system on the ship's bridge).

The ice conditions were determined by the observer estimating the ice coverage of each category of ice, ranging from open water to multi-year ice, in the immediate vicinity of the ship.

For confirmation of the ice conditions, photographs were taken from the ship's bridge of the port, starboard and bow views. An experimental set of photographs was taken of the radar screen. This proved most effective in the outer marginal ice zone in locating and displaying the extent of ice bands (see figure), which ran parallel to the ships course.

The use of video recording of the bow view proved very useful on previous cruises to the region (Odden'97, Scoresby 2000, CONVECTION 2001), and again a video of the bow view was made. This provides a continuous record of the actual ice conditions in daylight hours, which can be combined with the on-board ships computer which logs pitch, roll and heave of the ship, wind speed and direction, air pressure, and air temperature every second. However, this will be reduced to readings every minute, which is more than adequate for scientific purposes of the Ice Watch. One important consideration is that the video and computer log are set to the same time. Otherwise, comparisons may become confused.

In effect, technological advances have superseded, but not replaced, the Ice Watch. Rather, the Ice Watch will be used to confirm any analysis made from the digital record.

Date:/Time:	20/02/02 10:00	**Latitude:**	73º30.000'N	**Longitude:**	011º39.900'W
Observation No.:	XXI		Observer:	PW	

Port Photo:	DCP_0680.JPG	**Bow Photo:**	DCP_0681.JPG	**Starboard Photo:**	DCP_0682.JPG



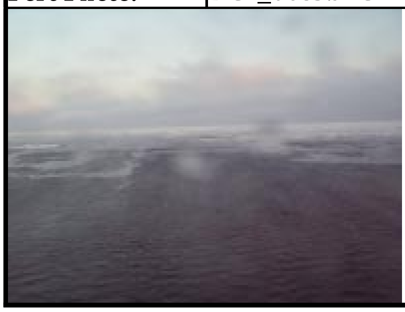
Concentrations:	
Open Water	5
Total Ice	95
Ice Types:	
Grease/Slush Ice	5
Pancake Ice	70
Dark Nilas	
Light Nilas	
Grey/Grey-White Ice	
1st Year Ice	
2nd Year Ice	
Multi Year Ice	20
Brash Ice	

Narrative:

Very large, old rimmed pancakes in amongst "open pack" of ulti-year floes, typical diameter 30-50m and snow covered.

Date:/Time:	20/02/02 11:00	**Latitude:**	73º29.900'N	**Longitude:**	011º44.500'W
Observation No.:	XXII		Observer:	PW	

Port Photo:	DCP_0683.JPG	**Bow Photo:**	DCP_0684.JPG	**Starboard Photo:**	DCP_0685.JPG



Concentrations:	
Open Water	30
Total Ice	70
Ice Types:	
Grease/Slush Ice	20
Pancake Ice	40
Dark Nilas	
Light Nilas	
Grey/Grey-White Ice	
1st Year Ice	
2nd Year Ice	
Multi Year Ice	10
Brash Ice	

Narrative:

Pancake ice consists of big, multiple floes with high rims.
Multi-year ice contains some floes with big ridges. Typical floe size 50m.
In real polar conditions. Very cold out (-18.1 C). Frost smoke visible, much open water created by wind, frazil, old floes, pancakes, everything. Typical East Greenland Current in winter.

Ship planning en route

Communications on the "Lance" were good with email, phone and fax working at most times of the day. Email communication enabled passive microwave ice concentration maps, weather charts and ice charts produced from the Radarsat images to be sent in near real time. These charts were extremely useful for the advance planning of work to be performed on board. In fact without these charts we would have been running blind with respect to the ice conditions and to some extent weather. All charts were too big to be delivered via Inmarsat C, as a result the Communicator dial up functionality was used to download the messages via Inmarsat A or preferably Iridium. All charts were passed on to the Captain.

Ice Charts

Information on the ice conditions for the region came from 5 sources: Passive microwave ice maps, Ice maps derived from Radarsat images, scatterometer images, AHVRR images and ice charts from the Norwegian Meteorological Institute.

Ice images

Daily passive microwave data from NASA's Marshall Space Flight Center were processed into various ice concentration images DCRS/DTU and were emailed directly to the ship by Leif Toudal. The swath width of the SSM/I sensor is some 1400 kilometres and it is therefore possible to obtain several images of the Greenland Sea every day. However, the antenna footprint on the ground is about 60 kilometres wide at the longest microwave wavelength (ca. 1.55 cm ~ 19 GHz) and approximately 15 kilometres at the shortest wavelength (3mm ~ 85 GHz). The longer wavelength penetrates clouds better, but even the shortest wavelength data are far superior to thermal infrared or visible data. The satellites pass the Greenland Sea area between 0800 and 1200 in the morning (descending orbits) and again between 1500 and 1900 in the evening (ascending orbits). Once processed the ice concentration images were zipped to reduce their size for transmission. Once unzipped the resulting ice chart were read into DTU's in house software. This enabled the ice conditions over the entire Greenland Sea to be accessed. Furthermore the software has the facility to zoom in and out, overlay bathymetry, coastlines, latitude and longitude grids etc. These features were used to produce daily ice charts of the region. An example of an ice chart produced by the software can be seen above. Resolution 25km x 25 km. All images used during the cruise as well as for the rest of the winter can be accessed through the DCRS web site http://www.dcrs.dtu.dk/DCRS/latest-ice.html.

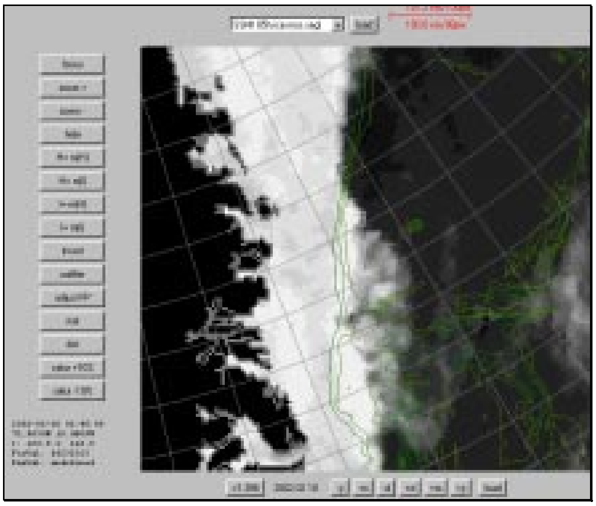
DTU also sent the 85GHz channel as a separate file as the resolution of this channel is higher, 12.5km. Furthermore, daily scatterometer, and the AMSU products were also sent.

One Radarsat images was obtained during the voyage, on March 2. This image was decoded by the Danish Meteorological Institute and an ice chart produced from the image by their experienced staff. The resulting ice chart was faxed to the ship They both can be seen below.

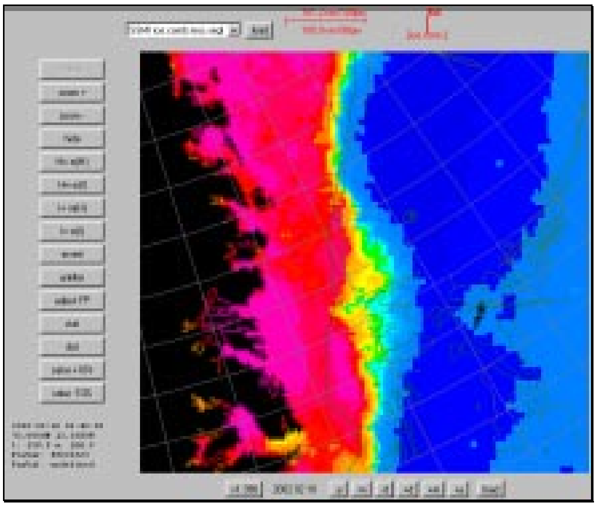
The high resolution of Radarsat images (25 m x 25 m pixel size) enabled the ice conditions to be documented extremely accurately. Radarsat is an advanced radar system that utilizes the Synthetic Aperture Radar (SAR) principle that allows image generation with a spatial resolution of about 50 metres and a swath width of approximately 500 kilometres. The images are excellent for getting high resolution information about the ice cover. The ice charts produced from the Radarsat image were used extensively in the planning of the ice work.

AVHRR

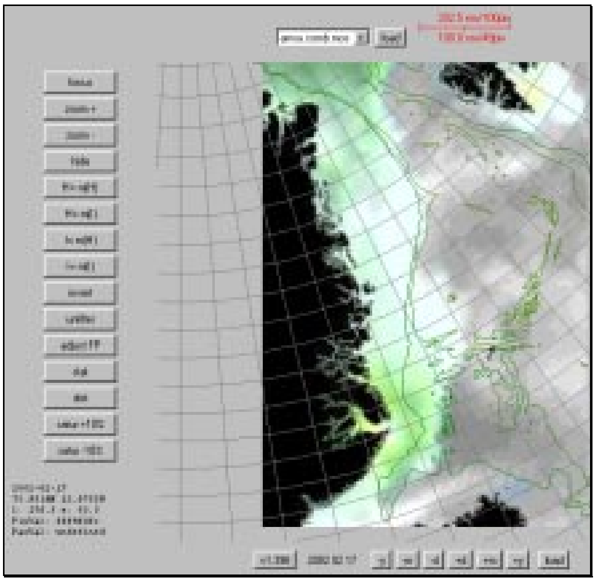
Cloud free AVHRR images were processed and emailed directly to the ship by Flavio Parmiggiani (ISAO-CNR, Bologna). AVHRR is a 5 channel visible and infra-red instrument which flies on the NOAA satellite system. Only a few cloud free images were available during the cruise, however they were valuable in planning for the ice physics work.



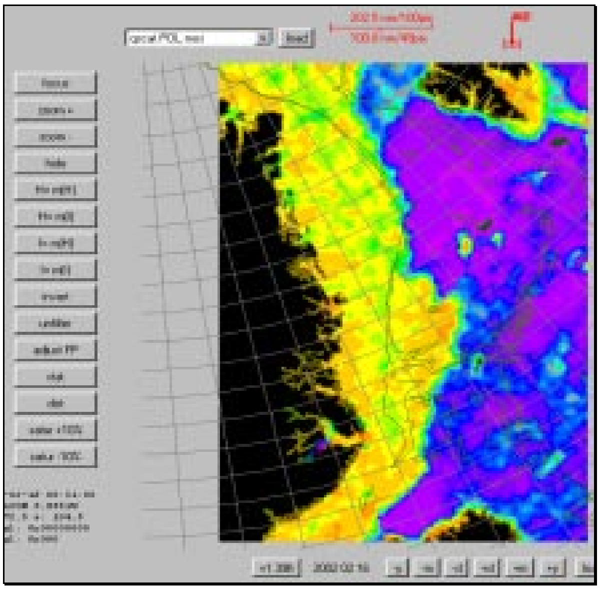
85 Ghz ice chart (10 Feb). Also shown is the DTU browser that reads the images.



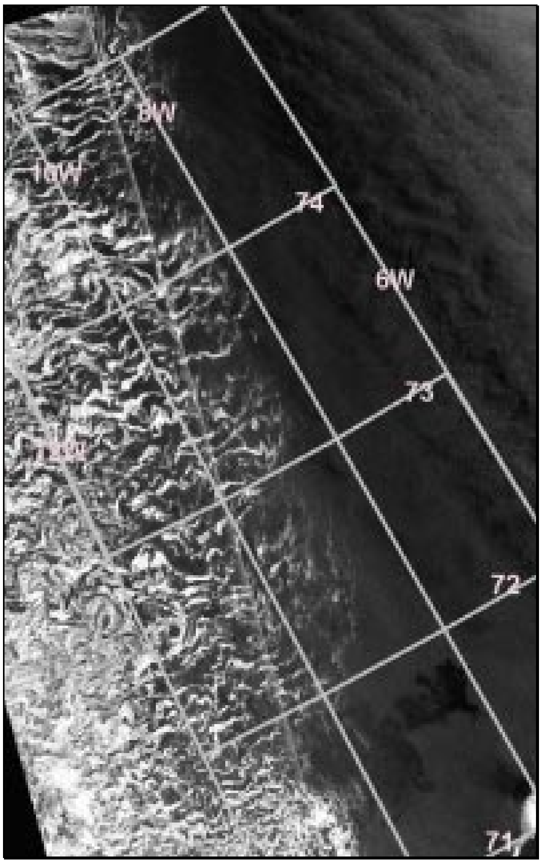
SSM/I ice concentration chart (10 Feb)



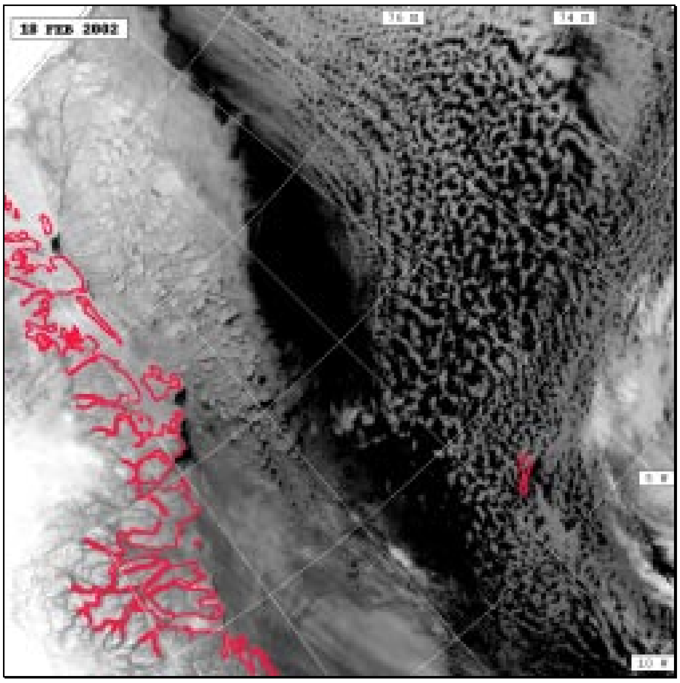
AMSU (17 Feb)



Quikscat (16 Feb)



Radarsat image



AVHRR image from the 18 Feb.

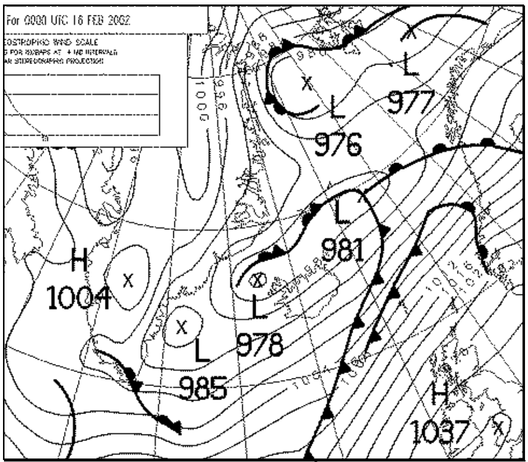
Weather Charts

Norwegian Meteorological Institute

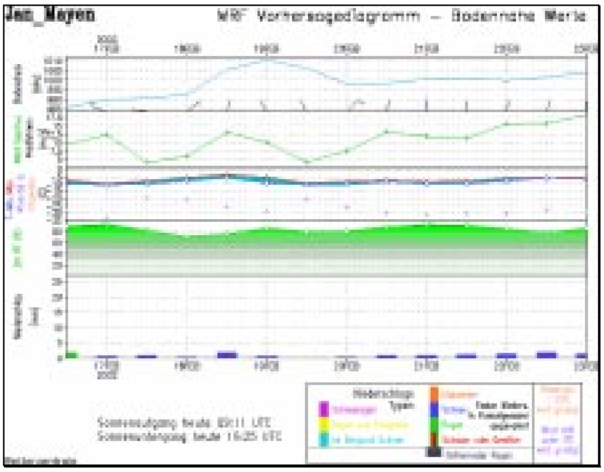
Weekly ice charts are produced by Norwegian Meteorological Institute. These charts are compiled from AVHRR (1.5 km resolution), SSM/I (25 km) and ship observations. The "Lance" receives the weekly chart by fax. Ice conditions can change dramatically in a week. As a result these charts are of limited value as the days pass.

UK Meteorological Office

Weather maps from UK Met Office/University of Bari and meteorological forecasts for Jan Mayen Island were received daily via email from Leif Toudal. The data consist of analysis charts of mean sea level pressure as well as 24, 48, 72 and 96 for the Nordic Seas and 7 day forecasts or Jan Mayen Island. We used primarily the 24 hour forecasts. These charts proved very useful for cruise planning as we were too far north to receive daily charts by any other means. These charts were supplemented by 6 hourly weather information through the NAVTEX system and radio. Weather information from the 7 day meteorological prediction for Jan Mayen Island was used to 'guess' how the ice would react to the air temperatures and wind field for the region. An example of the charts can be seen below.



0000UTC forecast for the 16th Feb 2002 from the UK Meteorological Office



7 day Meteorological prediction for Jan Mayen Island.

AUV surveys under arctic ice

Introduction

The main purpose of bringing an AUV along on the Convection 2002 Winter Cruise was to measure ice thickness. This goal was reached during two surveys on the 27th February, where the AUV were sent 700m and 1000m in under a band of drifting ice. The depth of the vehicle was 20 m and 10 m respectively.

The vehicle

The MARIDAN M150 AUV was first commissioned in January, 1996, and was released for commercial surveys in January, 2000. The basic dimensions are: length 4.5m, beam 1.1m (2m incl. Ailerons), height 0.6m. Dry weight is 900 kg.

Fig.1

Figure 1. shows the vehicle during ballasting prior to the Sea Acceptance Trials for this project on the 31st January, 2002, already mounted with the specific instruments for this project.

Survey Results

AUV Track

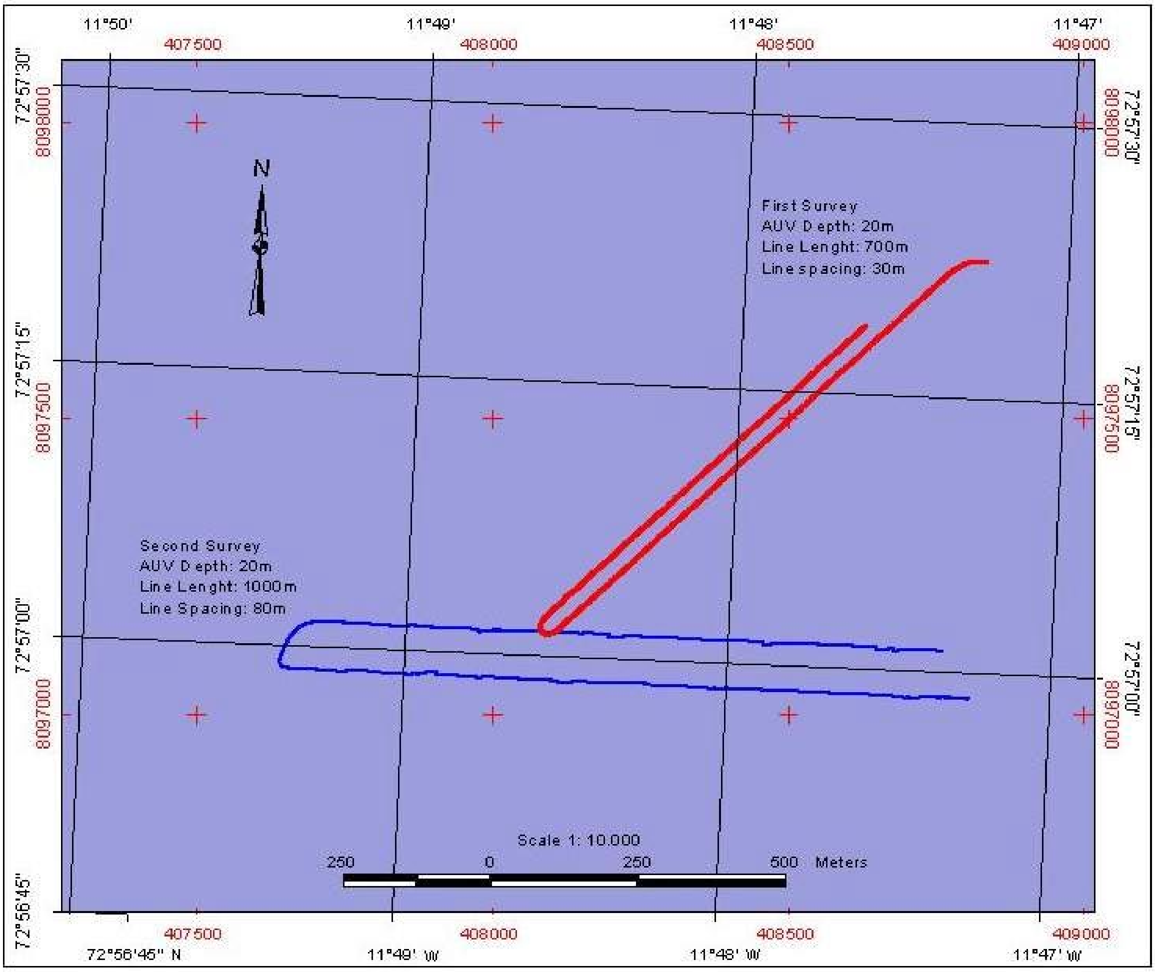


Fig. 2.

The above chart shows an approximate track of the AUV. All co-ordinates are in WGS84, UTM Zone 29, Central Meridian 9° W. Due to both the current and the wind, the whole band of ice was drifting southwards with about one knot.

1st survey at 20 m depth

Table 1. below show the preliminary results of the CTD sensor and vehicle performance. The actual results may vary following a re-calibration of the CTD sensor. Comparison to other instruments show that the AUV temperature sensor could be 0.25°C too low, and the conductivity similarly 0.25 mS/cm too low.

Survey 11:37	Roll, deg.	Pitch, deg.	Speed, m/s	Cond., µS/m	Temp., deg. C	Salinity, PSU	Depth, m
Min.	0.72	-9.32	0.90	2766479	-1.92	35.338	19.60
Max.	3.80	0.61	1.70	2773990	-1.86	35.403	20.47
Avg.	1.94	-1.10	1.34	2770376	-1.90	35.390	19.83
St.dev.	0.35	0.61	0.22	1481.62	0.02	0.0128	0.10

Table 1.

The results from the Sidescan Sonar and the upward looking ADCP indicates that the AUV has been under ice floes of maximum draft of 3.0m during this survey, as indicated on figure 3. below.

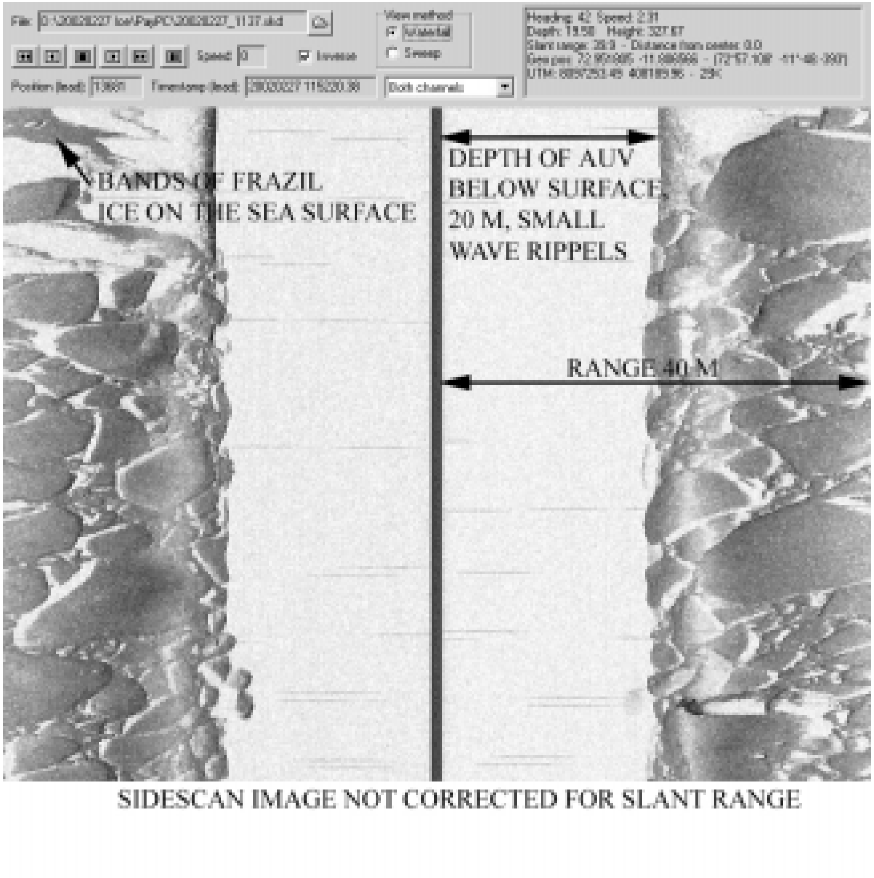


Figure 3.

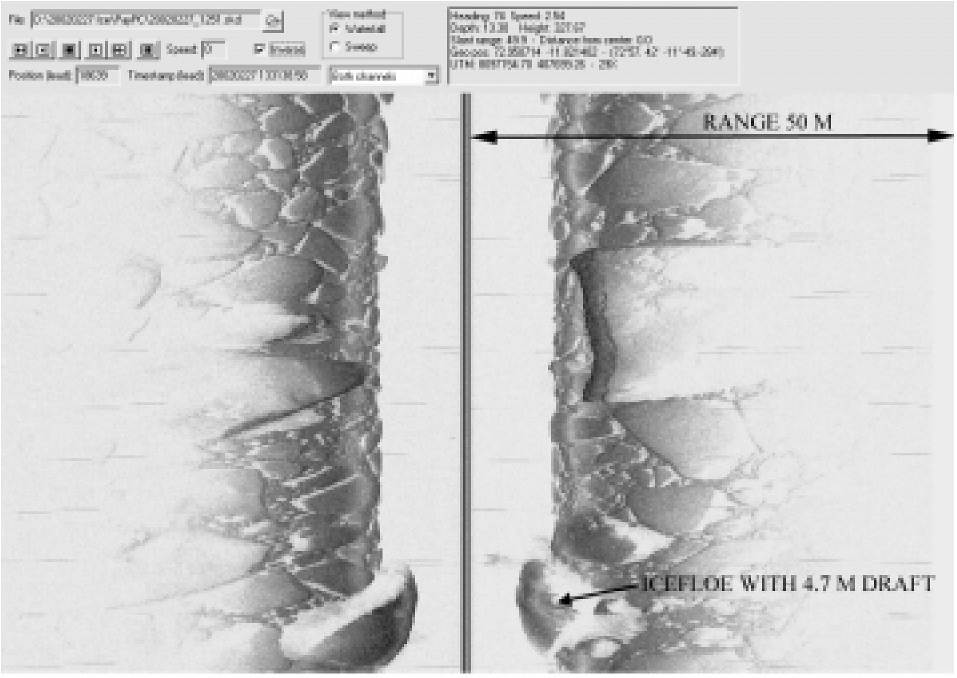
2nd survey at 10m depth

Table 2. shows the preliminary results from the 2nd survey, where the AUV was sent one kilometre in under the ice and back. Based on the results from the 1st survey, which was downloaded from the AUV between the surveys, it was decided that it was safe to send the AUV along at 10 m below surface.

Survey 13:13	Roll, deg.	Pitch, deg.	Speed, m/s	Cond., µS/m	Temp., deg. C	Salinity, PSU	Depth, m
Min.	0.40	-7.62	0.75	2768590	-1.92	35.40	9.49
Max.	4.47	0.34	1.50	2774640	-1.86	35.42	10.31
Avg.	2.25	-1.48	1.18	2772313	-1.88	35.41	9.77
St. dev.	0.48	0.63	0.16	1417.52	0.01	0.004	0.10

Table 2.

Figure 4. below shows the Sidescan image from the survey where the AUV passes under an ice floe with a draft of 4.7m. When a survey is completed, the AUV stops and surfaces by its positive buoyancy. But in this case, the ice had drifted over the location, and the AUV surfaced in between the ice floes. That meant that it took some time for us to find it, assisted, though, by the VHF beacon on the AUV.



SIDESCAN IMAGE NOT CORRECTED FOR SLANT RANGE