NP TRACTOR, October 2001

Chief scientist: Dr Jane O'Dwyer, NP

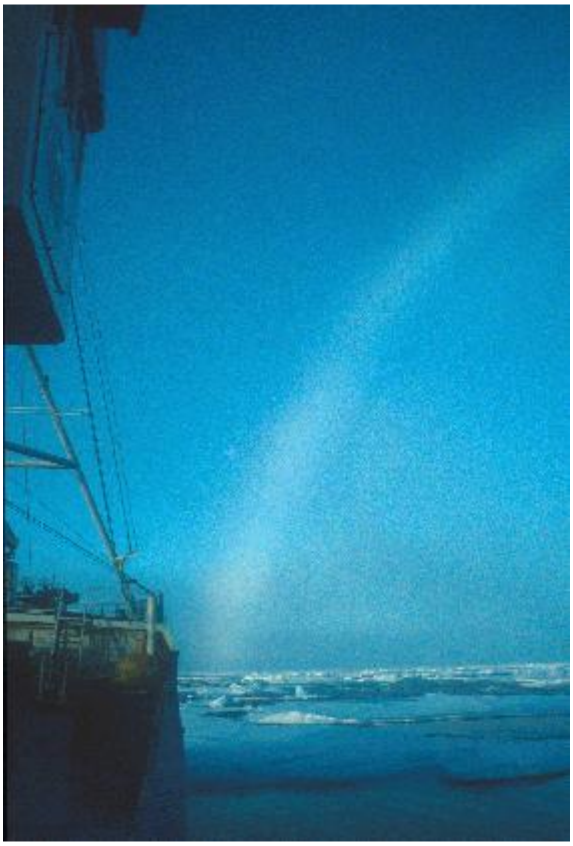

Photo by Janus Larsen

1. Background

The NP TRACTOR cruise in October 2001 continued NP's annual occupation of the Fram Strait hydrographic section at 79°N. In addition work was carried out for the EU-funded TRACTOR and Convection projects that NP participates in, and for the Norwegian NOClim project.

The cruise had three parts:

1. The annual Fram Strait CTD section. Water samples for SF_6 analysis were collected for the TRACTOR project, and samples for oxygen isotope analysis were collected for the NOClim project.
2. The deployment of acoustic moorings on the Vesteris Seamount for the Convection project.
3. A resurvey of the anomaly in the central Greenland Gyre that had been observed in the spring of 2001 during Convection project cruises.

2. Participants

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3. Cruise narrative

See the map in Figure 1 and the station list in Table 1 for details of station positions and times.

R/V Lance left the port of Longyearbyen, Spitzbergen, at 16:00, October 2nd 2001 (all dates and times are given in ship's time, GMT+2). The hydrographic section in the Fram Strait at 79°N began at the Spitzbergen coast at 04:00, October 3rd, and worked westward. At 17:00, October 4th, after completing the first 18 stations, Lance reached the ice edge at 1°W. Whilst in the ice CTD casts were only possible during daylight hours, because of lack of visibility of drifting ice at night. An attempt was made to continue westwards, however at 08:30, October 5th the attempt to reach the next station, at 2°W was abandoned and station 19 was carried out at 1°25.5'W. In order to obtain measurements and water samples from the East Greenland Current and the shelf, the section was resumed at 77°N, where the ice map indicated more open ice conditions. Stations 20 to 22 continued the section to 4°W, although it was necessary to move still further south to 76°48.4'N for station 22 due to the heavy ice that was again encountered. Two further attempts to continue west at 76°N and 75°N showed that the ice edge lay approximately along the 2000 m depth contour, blocking access to the shallower shelf regions. The ice maps showed that the ice edge was moving southwards and eastwards, and the section was therefore finally abandoned at 03:00 on October 7th and Lance sailed for the Vesteris seamount.

Lance arrived at Vesteris, at approximately 73°30'N, 9°W, at 00:00 on October 8th. Three acoustic moorings were deployed during the next 36 hours, finishing at 11:15, October 9th.

Finally Lance proceeded to the resurvey of the convection site near 75°N, 0°E. The hydrographic survey started at 07:00 on October 10th. The survey was halted at 21:00, due to strong winds. However the weather improved during the night and CTD work was resumed at 06:00 the next morning. At 18:00 on October 13th the survey was completed and Lance sailed for Longyearbyen.

In total 48 CTD casts were carried out at 44 stations, 114 water samples were collected for oxygen isotope analysis, 137 for SF_6 analysis, and 74 for CTD salinity calibration. A description of the CTD data collection and processing is given in the appendix. Shipmounted ADCP data were collected during the CTD work, and 3 acoustic moorings were deployed.

Figure 1: Map of CTD stations (stars) and rig deployments (square)

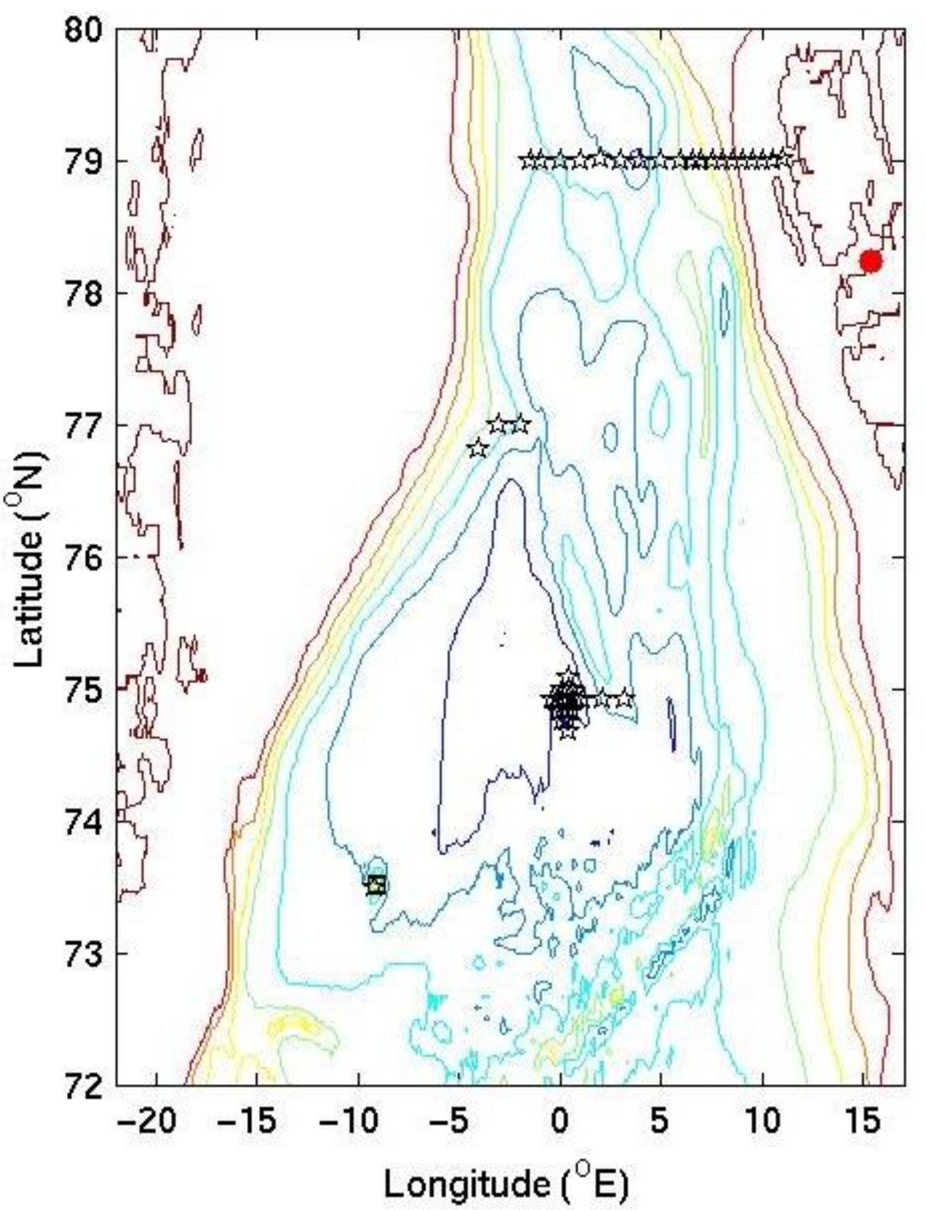


Table 1: CTD stations carried out during the cruise. Fram Strait stations are labelled FS, the Vesteris station is labelled V, and the convection stations are labelled C.

Station	Date	Time (GMT+2)	Latitude	Longitude	Depth (m)
FS00101	031001	0405	79°00.10'N	011°00.60'E	285
FS00201	031001	0555	79°00.00'N	010°30.50'E	280
FS00301	031001	0655	79°00.00'N	010°00.40'E	262
FS00401	031001	0805	79°00.00'N	009°30.00'E	202
FS00501	031001	0910	79°00.00'N	009°00.00'E	206
FS00601	031001	1025	79°00.00'N	008°30.00'E	476
FS00701	031001	1140	79°00.00'N	008°00.30'E	1078
FS00801	031001	1320	79°00.00'N	007°30.70'E	1225

FS00901	031001	1505	79°00.00'N	007°00.00'E	1230
FS01001	031001	1650	79°00.00'N	006°30.50'E	1394
FS01101	031001	1850	79°00.00'N	006°00.20'E	1851
FS01201	031001	2150	79°00.00'N	004°59.80'E	2400
FS01301	041001	0100	79°00.00'N	004°00.00'E	2711
FS01401	041001	0420	79°00.00'N	002°59.80'E	2529
FS01501	041001	0725	79°00.10'N	001°59.80'E	2467
FS01601	041001	1040	79°00.00'N	001°00.00'E	2525
FS01701	041001	1330	79°00.00'N	000°00.10'E	2549
FS01702	041001	1402	78°59.90'N	000°00.10'E	2548
FS01801	041001	1710	79°00.00'N	001°00.10'W	2603
FS01901	051001	0910	79°00.00'N	001°25.50'W	2589
FS02001	051001	2350	77°00.00'N	002°00.00'W	3105
FS02002	061001	0035	77°00.00'N	002°00.00'W	3105
FS02101	061001	0405	77°00.00'N	003°00.00'W	2632
FS02102	061001	0445	77°00.00'N	003°00.00'W	2632
FS02201	061001	0910	76°48.40'N	004°01.30'W	2209
FS02202	061001	0950	76°48.40'N	004°01.30'W	2209
V02301	091001	1100	73°29.20'N	009°13.50'W	624
C02401	101001	0710	74°50.00'N	000°24.00'E	3712
C02501	101001	1020	74°55.50'N	000°24.00'E	3710
C02601	101001	1310	74°55.00'N	000°38.80'E	3711
C02701	101001	1646	75°05.00'N	000°23.80'E	3708
C02801	111001	0815	74°55.00'N	000°09.20'E	3708
C02901	111001	1110	74°55.00'N	000°06.00'W	3706
C03001	111001	1420	74°50.00'N	000°06.00'W	3705
C03101	111001	1720	74°50.00'N	000°08.90'E	3707
C03201	111001	2030	74°45.00'N	000°23.90'E	3710
C03301	111001	2350	74°50.00'N	000°39.00'E	3712
C03401	121001	0320	74°59.90'N	000°39.20'E	3711
C03501	121001	0610	75°00.00'N	000°23.90'E	3707
C03601	121001	0900	75°00.00'N	000°09.00'E	3706
C03701	121001	1240	74°55.00'N	000°21.00'W	3700
C03801	121001	1600	74°55.00'N	000°50.00'E	3691
C03901	121001	2030	74°53.00'N	000°17.10'E	3710
C04001	131001	0005	74°45.00'N	000°09.10'E	3667
C04101	131001	0310	74°40.10'N	000°23.90'E	3724
C04201	131001	0740	74°55.00'N	001°09.00'E	3712
C04301	131001	0145	74°55.00'N	002°09.00'E	3077
C04401	131001	1530	74°55.00'N	003°09.00'E	3180

4. Fram Strait hydrographic section

P.I. Dr Jane O'Dwyer, NP

Introduction

The Fram Strait is the main link between the Arctic Ocean and the Nordic Seas to the south and is well-placed for monitoring of changes in the hydrography of these basins and transports between them. The cruise continued the series of CTD sections in the Fram Strait that have been carried out by NP since the 1980s. The TRACTOR project adds a new tool by using the presence of the tracer SF_6 to measure these exchanges.

The main goal of TRACTOR is to gain information to improve, test and validate ocean general circulation models for the North Atlantic Current system, the North Atlantic sub-polar gyre, the Nordic Seas, and the Eurasian part of the Arctic Basin. The project utilises the deliberate release of SF_6 tracer to the convective gyre of the Greenland Sea in 1996 during the European Sub-Polar Ocean Programme (ESOP). As of 2001, a large portion of the tracer still resides in the gyre and some is in transit to other ocean basins (Norwegian Sea, Arctic Ocean and North Atlantic). Since the initial conditions are known, it is possible to quantify a number of important parameters and test model results by direct comparisons with the observations.

The Fram Strait is the main deep link between the Greenland Sea and the Arctic. Measurements of SF_6 concentrations in the Fram Strait will give information about mixing and circulation in the Greenland Sea, and the rates and pathways of flows into the Arctic Ocean.

Sampling strategy

The positions of the CTD stations are shown on the map in Figure 1. The station spacing is 1° longitude over the flat topography in the centre of the strait or near the coast. Over the shelf slope, where the main currents are observed, the station spacing is reduced to 1/2° longitude.

The tracer, SF_6, was released in the Greenland Gyre on the isopycnal sigma-theta=28.0492, which lies at a depth of around 800 to 1000 m in the Fram Strait. Water samples were taken on this isopycnal and at the following distances above and below: 50 m, 100 m, 200 m, 400 m and 600 m. The samples were stored in the cold room on Lance and after the cruise sent to Marie-Jose Messias, University of East Anglia, for analysis.

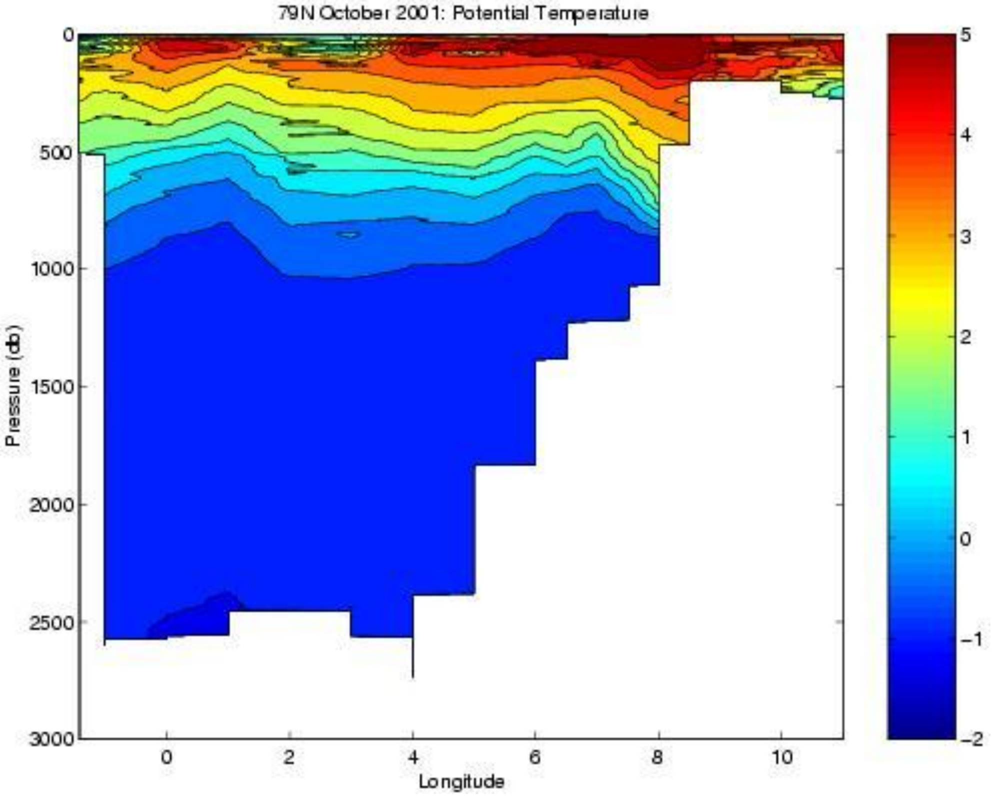
The oxygen isotope analysis is used to determine the origins of the freshwater flowing out of the Arctic Ocean. Sampling is concentrated in the surface layers of the East Greenland Current in the west of the section. Samples were taken at the following depths: surface, 10 m, 20 m, 30 m, 50 m, 100 m, 150 m, 200 m, 300 m, 400 m and 500 m. The water samples were sent to Truls Johannessen, University of Bergen, for post-cruise analysis.

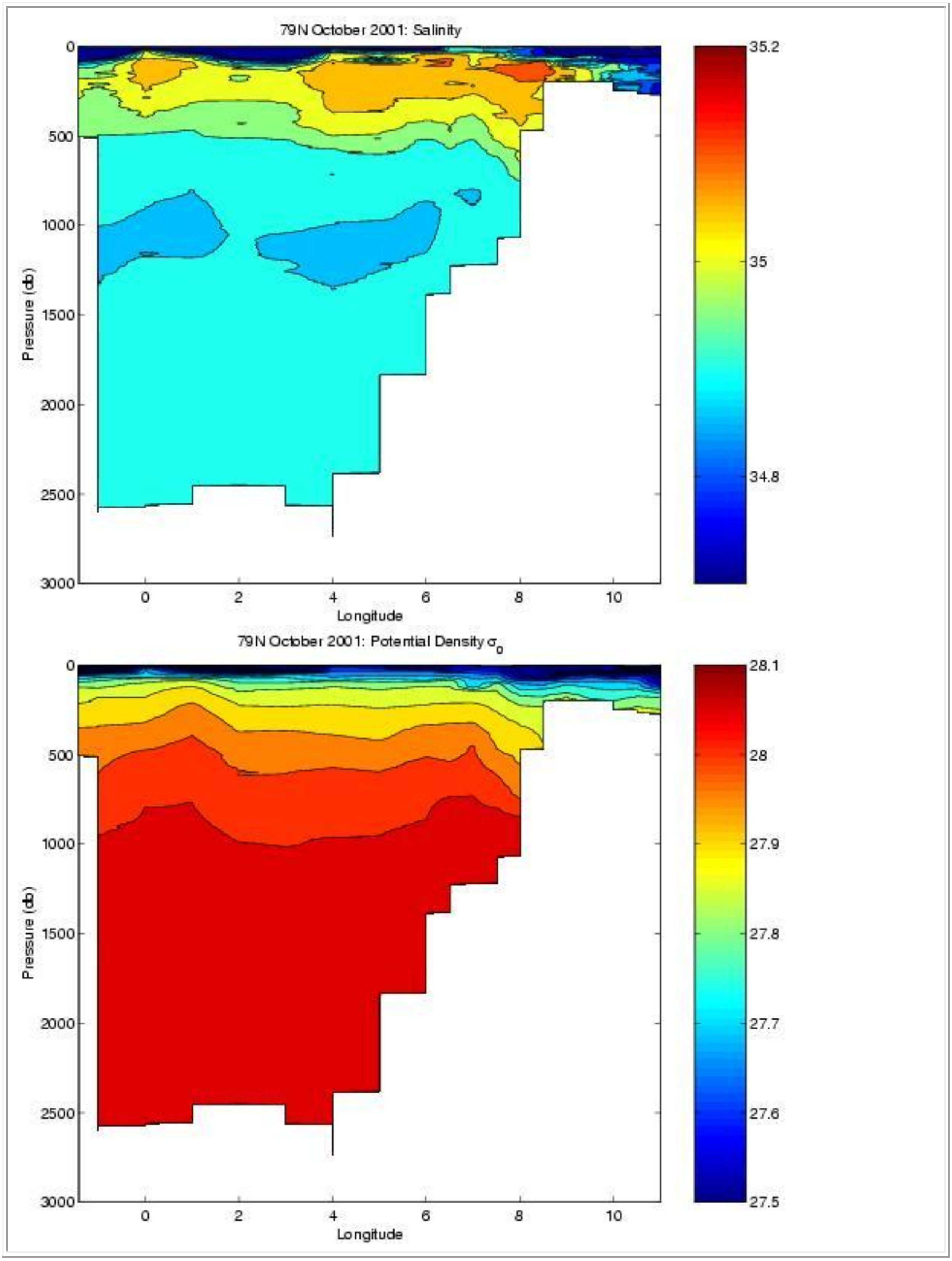
On each cast a sample for salinity calibration was taken at the bottom of the cast. On deeper casts a sample was also taken from the second-deepest bottle. The samples were sent to the University of Bergen for post-cruise analysis. The calibration of CTD salinity with the bottle samples is described in the appendix.

Results

The Fram Strait hydrography is shown in Figure 2. A surface layer of warm, fresh water extends across the entire section. Beneath this, between about 100 m and 500 m depth, is a layer of warm and saline water, derived from North Atlantic Water. The strongest core lies above the slope on the eastern side of the strait, where the Atlantic Water flows northwards into the Arctic Ocean. The smaller, weaker core on the western side is a southwards recirculation of part of the inflow. Below about 1000 m lies deep water from the Arctic and Nordic basins, in order of increasing salinity and temperature: Greenland Sea Deep Water, Norwegian Sea Deep Water, Eurasian Basin Deep Water and Canadian Basin Deep Water.

Figure 2: Potential temperature, salinity and density along the section at 79°N.





5. Acoustic Shadowgraph deployment

P.I. Dr B.J. Uscinski

Introduction

The "Convection" Project aims to study details of convection and heat transfer phenomena in the Greenland Sea. An important element in this study is the progress of near-surface convection and heat-transfer as the sea is cooled from above. The theoretical model developed by Prof. J. Backhaus of the Hamburg Institut fur Meereskunde predicts that when a fresh water surface layer is cooled it produces vertical convection cells that cause the colder water to descend in "plumes" with diameters of perhaps 200 m. These features can descend with momentum sufficient to "punch through" the thermocline. The present Acoustic Shadowgraph Trial aims at obtaining evidence to confirm the Backhaus model and, in addition, to ascertain how near-surface convection is affected by the formation of ice-cover during the winter.

Methods

In order to detect vertical convection we use the fact that the falling "plumes" have temperatures that are slightly different from that of the surrounding warmer water. The accompanying sound speed variations produce phase and intensity modulations on an acoustic wave that may propagate through the "plumes". The Acoustic Shadowgraph Method uses the moving intensity pattern to detect and measure the convection. A sound source at a depth of between 100 and 200 m emits 11 Khz pulses every 12 secs. The modulated wave-front is detected by two hydrophones with a vertical separation of 10 or 20 m moored at a distance of several kilometres from the source. If the pattern is moving in the vertical then the cross-correlation of the intensity registered at the top and bottom hydrophones will be offset from the time origin. The speed of vertical motion can be calculated from the time lag and hydrophone separation.

Experimental set up

It was planned to set the 3 moorings carrying the source and hydrophone pairs on the side of the Vesteris Bank Seamount in the West Greenland Sea. This would allow the near-surface layer to be studied without having to use very long mooring cables with their accompanying horizontal and vertical sway. The abyssal plain in the Greenland Sea could be of the order of 3500 m depth, but Vesteris rises to within 130 m of the surface. A notional mooring depth of 500 to 600 m was planned with the source and receiver in the range of 100 to 250 m from the surface. In addition Vesteris Bank is an area of the Greenland Sea that will be covered with pancake ice as the sea freezes whenever the Odden is formed.

Deployment

The R/V Lance arrived at Vesteris Bank and surveyed the proposed site for the source with sonar depth finders. The slopes of the seamount at this point were found to be very steep. Eventually a flat plateau-like area was located and Mooring 1 was launched at 73°31.23'N 9°03.75'W on Mon 8-10-01 at 10:00 hrs. The source was functioning correctly before launch. The R/V Lance then moved to the north-east by about 3 km and located a suitable flat site for the second mooring. One of the hydrophones was immersed to a depth of several metres and the pulse signal was acquired. The detection, digitizing, filtering and recording stages of the receiver package were tested and found to be functioning correctly. The receiver Mooring 2 was launched at 73°31.45'N and 9°02.22'W on Mon 8-10-01 at 17:00 hrs. The hydrophone separation on this mooring was 20 m. During the night R/V Lance moved to the south-west of the source and located a suitable flat launch site. Mooring 3 was launched at 73°30.65'N and 9°07.50'W on Tuesday 9-10-01 at 10:20 hrs.

Instrumentation

Mooring 1 had a single Aanderaa current meter at a depth of 114 m that measured current strength but not direction. The acoustic source was situated at a depth of 140 m and the bottom was at a depth of 525 m. Mooring 2 carried two hydrophones, one at a depth of 230 m and another at 250 m. The bottom was at a depth of 620 m. Mooring 3 also carried two hydrophones, one at a depth of 180 m and the other at a depth of 190 m. The bottom was at a depth of 565 m.

6. Hydrographic survey of Greenland Gyre anomaly

P.I. Dr Vladimir Pavlov

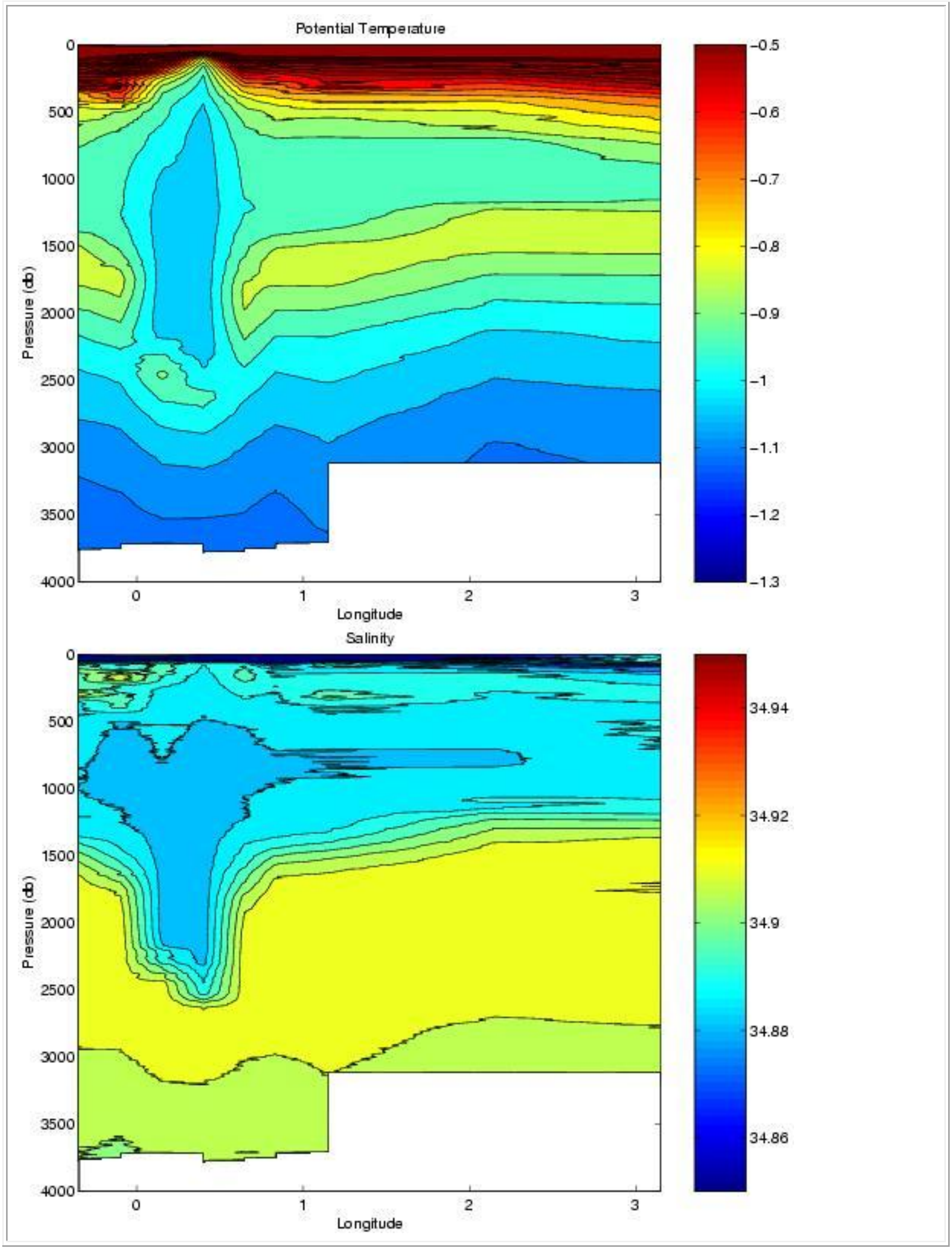
Introduction

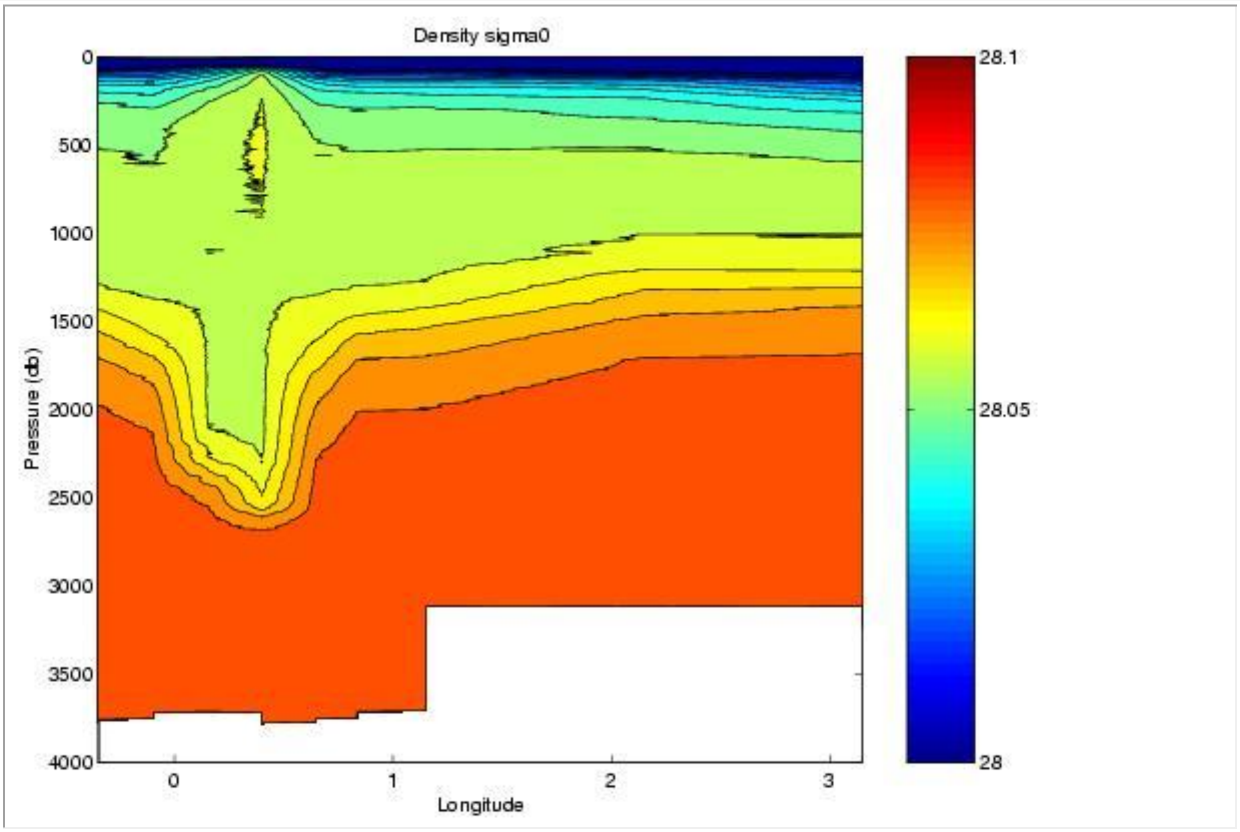
On the NP Convection cruise in April 2001 a CTD survey was carried out of an anomaly in the hydrographic structure at the centre of the Greenland Gyre, which was identified as being a site of deep convection. During the TRACTOR cruise we returned to this site in order to observe any changes that had taken place during the summer.

Results

Figure 3 shows that the anomaly was still present, and the position was almost unchanged since the spring. A cap of warm, fresh water had formed at the surface, but beneath this thin layer, the anomaly formed a symmetrical 'chimney' about 20 km across and 2500 m deep that remained nearly as strong as in April. Above about 1000 m, temperature and salinity were lower, and density higher than in the surrounding water. Below 1000 m the anomaly in density was reversed.

Figure 3: Potential temperature, salinity and density along 74°55'N in the Greenland Gyre.


Potential Temperature
Pressure (db)
Longitude
0
500
1000
1500
2000
2500
3000
3500
4000
0
1
2
3
−0.5
−0.6
−0.7
−0.8
−0.9
−1
−1.1
−1.2
−1.3
Salinity
Pressure (db)
Longitude
34.94
34.92
34.9
34.88
34.86



Appendix: CTD data

Shipboard data collection and processing

Conductivity, temperature and pressure were measured using a Sea-Bird Electronics 911plus CTD. Primary and secondary temperature and conductivity sensors were newly calibrated by the manufacturer before the cruise. The data was first processed using SBE Data Processing software. The main steps were: conversion to ASCII format, removal of conductivity cell thermal mass effects, low pass filtering of conductivity and pressure records, removal of data points where the CTD was moving slowly or backwards, and finally averaging into 1 db bins. The processing steps are recorded in the data file headers, as shown in Figure 4. Further processing and analysis used data from the primary CTD sensors, taken from the downcasts.

Figure 4: Data file header generated by SBE Data Processing software for CTD cast FS00101. The same processing parameters were used for all the casts.

```
* Sea-Bird SBE 9 Raw Data File:
* FileName = C:\Sea-Bird\ctddata\fs00101.dat
* Software Version Seasave Win32 v1.18
* Temperature SN = 2400
* Conductivity SN = 2056
* Number of Bytes Per Scan = 21
* Number of Voltage Words = 1
* Number of Scans Averaged by the Deck Unit = 1
* System UpLoad Time = Oct 03 2001 02:23:53
** Ship: Lance
** Cruise: TRACTOR
** Station:    fs001
** Cast: 01
```

```
** Date: 031001
** Time (GMT+2): 0405
** Latitude: 79 00.1 N
** Longitude: 11 00.6 E
** Depth: 285
# nquan = 13
# nvalues = 283
# units = specified
# name 0 = scan: Scan Count
# name 1 = prDM: Pressure, Digiquartz [db]
# name 2 = t090C: Temperature [ITS-90, deg C]
# name 3 = c0S/m: Conductivity [S/m]
# name 4 = t190C: Temperature, 2 [ITS-90, deg C]
# name 5 = c1S/m: Conductivity, 2 [S/m]
# name 6 = potemp090C: Potential Temperature [ITS-90, deg C]
# name 7 = sal00: Salinity [PSU]
# name 8 = sigma-é00: Density [sigma-theta, Kg/m^3]
# name 9 = potemp190C: Potential Temperature, 2 [ITS-90, deg C]
# name 10 = sal11: Salinity, 2 [PSU]
# name 11 = sigma-é11: Density, 2 [sigma-theta, Kg/m^3]
# name 12 = flag: flag
# span 0 =       1593,      10745
# span 1 =      2.000,    284.000
# span 2 =     1.0013,     5.0247
# span 3 =   2.981538,   3.332396
# span 4 =     1.0013,     5.0239
# span 5 =   2.982054,   3.332986
# span 6 =     0.9904,     5.0191
# span 7 =    33.8868,    34.8940
# span 8 =    26.9810,    27.8624
# span 9 =     0.9904,     5.0183
# span 10 =    33.8928,    34.9123
# span 11 =    26.9857,    27.8687
# span 12 = 0.0000e+00, 0.0000e+00
# interval = decibars: 1
# start_time = Oct 03 2001 02:23:53
# bad_flag = -9.990e-29
# sensor 0 = Frequency  0  temperature, primary, 2400, 14-Jul-01
# sensor 1 = Frequency  1  conductivity, primary, 2056, 12-Jul-01, cpcor =
-9.5700e-08
# sensor 2 = Frequency  2  pressure, 68996, 07-21-1997
# sensor 3 = Frequency  3  temperature, secondary, 2381, 26-Jul-01
# sensor 4 = Frequency  4  conductivity, secondary, 2063, 23-Aug-01, cpcor
= -9.5700e-08
# sensor 5 = Extrnl Volt  0  fluorometer, sea tech, ws3s-526p, 04/13/99
# sensor 6 = Extrnl Volt  1  surface irradiance (SPAR), degrees = 0.0
# datcnv_date = Oct 24 2001 10:22:40, 1.5
# datcnv_in = D:\ctddat\fs00101.dat D:\ctddat\fs00101.CON
# datcnv_skipover = 1640
# celltm_date = Oct 24 2001 10:36:04, 1.5
# celltm_in = D:\ctddat\fs00101.cnv
# celltm_alpha = 0.0300, 0.0300
# celltm_tau = 7.0000, 7.0000
# celltm_temp_sensor_use_for_cond = primary, secondary
# filter_date = Oct 24 2001 10:46:24, 1.5
# filter_in = D:\ctddat\fs00101.cnv
# filter_low_pass_tc_A = 0.030
# filter_low_pass_tc_B = 0.150
# filter_low_pass_A_vars = c0S/m c1S/m
# filter_low_pass_B_vars = prDM
```

```
# loopedit_date = Oct 24 2001 12:15:32, 1.5
# loopedit_in = C:\fram2001\fs00101.cnv
# loopedit_minVelocity = 0.100
# loopedit_excl_bad_scans = yes
# binavg_date = Oct 24 2001 12:27:43, 1.5
# binavg_in = C:\fram2001\fs00101.cnv
# binavg_bintype = decibars
# binavg_binsize = 1
# binavg_excl_bad_scans = yes
# binavg_skipover = 0
# binavg_surface_bin = no, min = 0.000, max = 0.000, value = 0.000
# Derive_date = Oct 24 2001 12:41:44, 1.5
# Derive_in = C:\fram2001\fs00101.cnv C:\fram2001\TRACTORB.con
# split_date = Oct 24 2001 12:44:39, 1.5
# split_in = C:\fram2001\fs00101.cnv
# split_excl_bad_scans = yes
# file_type = ascii
*END*
```

Post-cruise processing

The CTD salinities measured by the primary sensor were calibrated against the water samples taken for each cast. The water sample salinities were determined after the cruise at the Geophysical Institute, University of Bergen. For each sample the difference between the CTD salinity and sample salinity, $\Delta S = S_{CTD} - S_{bottle}$, was calculated. After removing one obvious outlier, the mean and standard deviation of ΔS were m=-0.0016 and s=0.0063 respectively. Points lying more than one standard deviation from the mean were then removed. The scatter for the shallower samples was large, so samples taken at depths less than 1000 m were also eliminated, leaving 43 samples for the calibration. A linear fit between ΔS and pressure gave the relation $\Delta S = -0.00451 + 1.42\times10^{-6}p$, where p is the pressure in decibars, and this was used to adjust the CTD salinities. After calibration the standard deviation of ΔS was 0.001.

The calibrated CTD data was checked for spikes and density inversions. Density inversions were removed when $\delta\rho/\delta z > 0.03$ kg m^{-3} db^{-1}, where this is the vertical gradient of in situ density, referenced to the midpoint of each pair of data points. Inversions corresponded to spikes over one or two points in either salinity or, less often, temperature. The spikes were removed and values interpolated to give a continuous profile.

http://www2.npolar.no/~jane/nptractor2001
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