GIANTS-RISOC* Cruise to the Southeastern Weddell Sea on R.R.S. Shackleton

Feb. 6-19, 2003

Preliminary Cruise Report

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* Global Interactions of the ANTarctic ice Sheet – Response of the Ice-Shelf Ocean system to Climate

Introduction

As part of an agreement between British Antarctic Survey (BAS) and the Bjerknes Centre for Climate Research at the University of Bergen (UiB), an oceanographic cruise was carried out in the southeastern Weddell Sea in February, 2003. The ship used was the RRS Ernest Shackleton, formerly the M/V Polar Queen of Bergen. This ship is now primarily used as a supply vessel, and does not carry much scientific equipment; hence the CTD equipment used was supplied by the Geophysical Institute at UiB (GFI), which borrowed a large part from UNIS, the University Centre on Svalbard, an LADCP was borrowed from the Faroese Fisheries Laboratory, and mooring components were supplied in part by UKORS at Southampton and in part by GFI. The initial plan was to deploy three BAS moorings near the Brunt Ice Shelf, then to take a section NW towards the middle of Filchner Sill, and then to take a section W along 74°40’ S as far as the ice would allow, dropping moorings S2 and S1 off en route. Finally, the main objective of the cruise was to survey the plume of Ice Shelf Water (ISW) emanating from the Filchner Depression, and flowing down the continental slope W of the depression. However, due to severe ice conditions, it was not possible to enter the plume area, and instead the area E of the depression and N of Brunt Ice Shelf was surveyed.

This report gives a quick overview of the data set, and explains some of the problems encountered during the cruise. A chronological cruise log is included as Appendix A, and Appendix B is a complete station list. The main text only describes the CTD profiles. For detailed information about the moorings, see Appendix A. The maps in figs. 1a and 1b show the locations of the moorings and CTD stations, while fig. 1c shows the route of the ship.

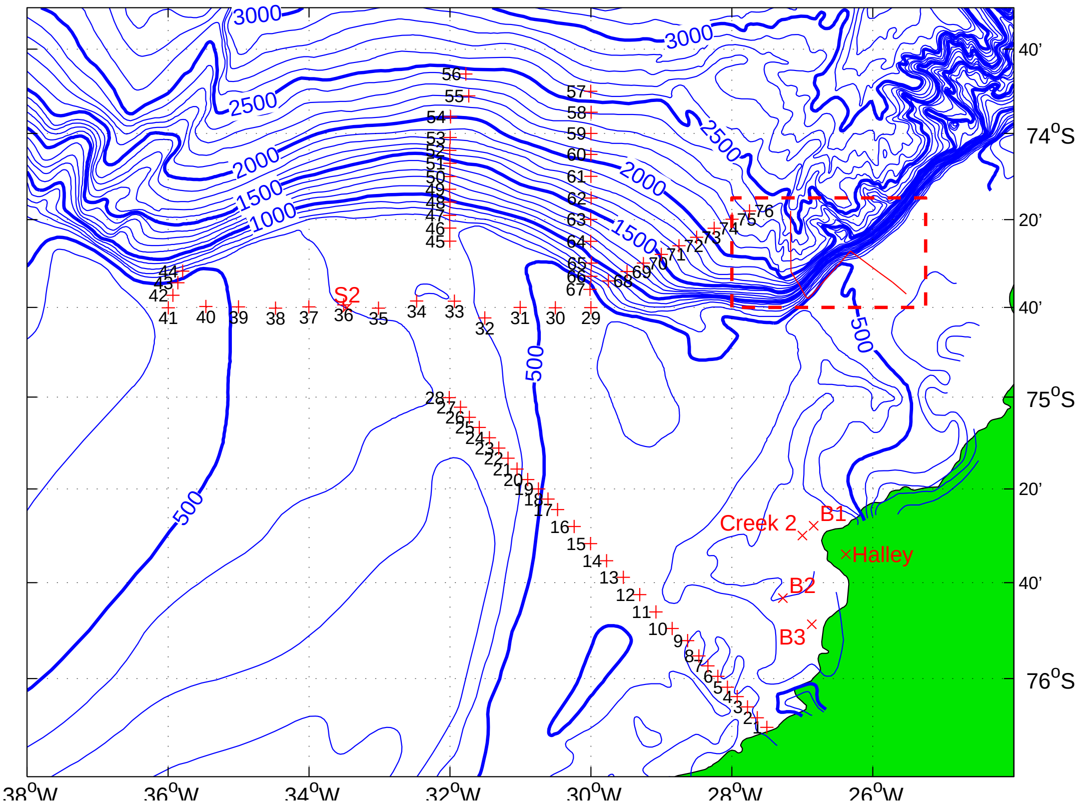

Fig. 1a. Map over CTD stations 1-76 and moorings B1-B3 and S2. The dashed box shows the area in fig. 1b. Bathymetric data is from GEBCO. The green coastline is out of date: Brunt Ice Shelf has moved SW approx. 5 miles.

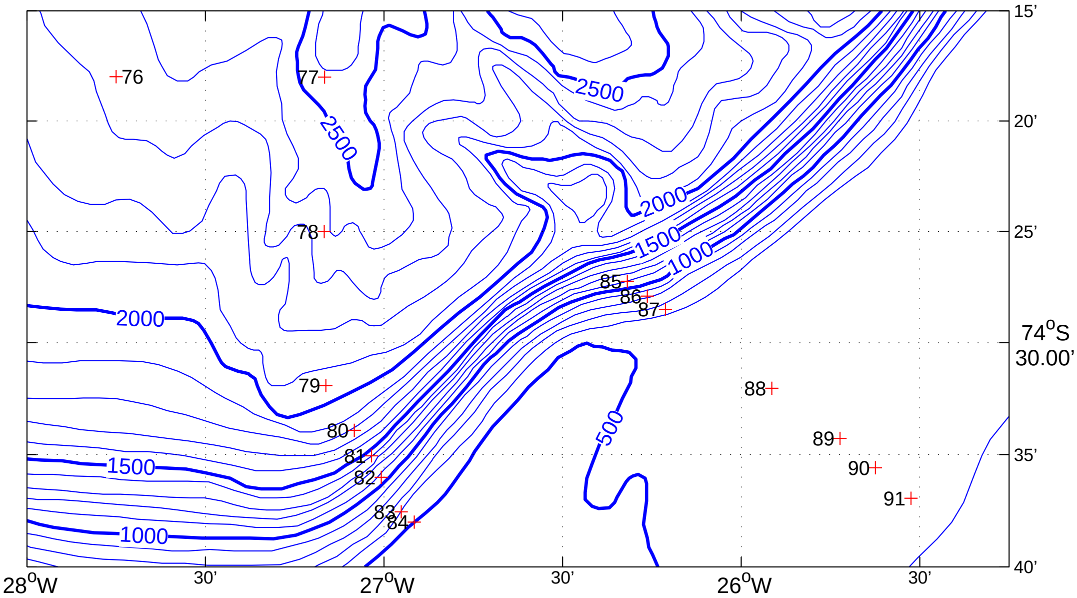

Fig. 1b. Map over CTD stations 76-91. Bathymetric data is from GEBCO.

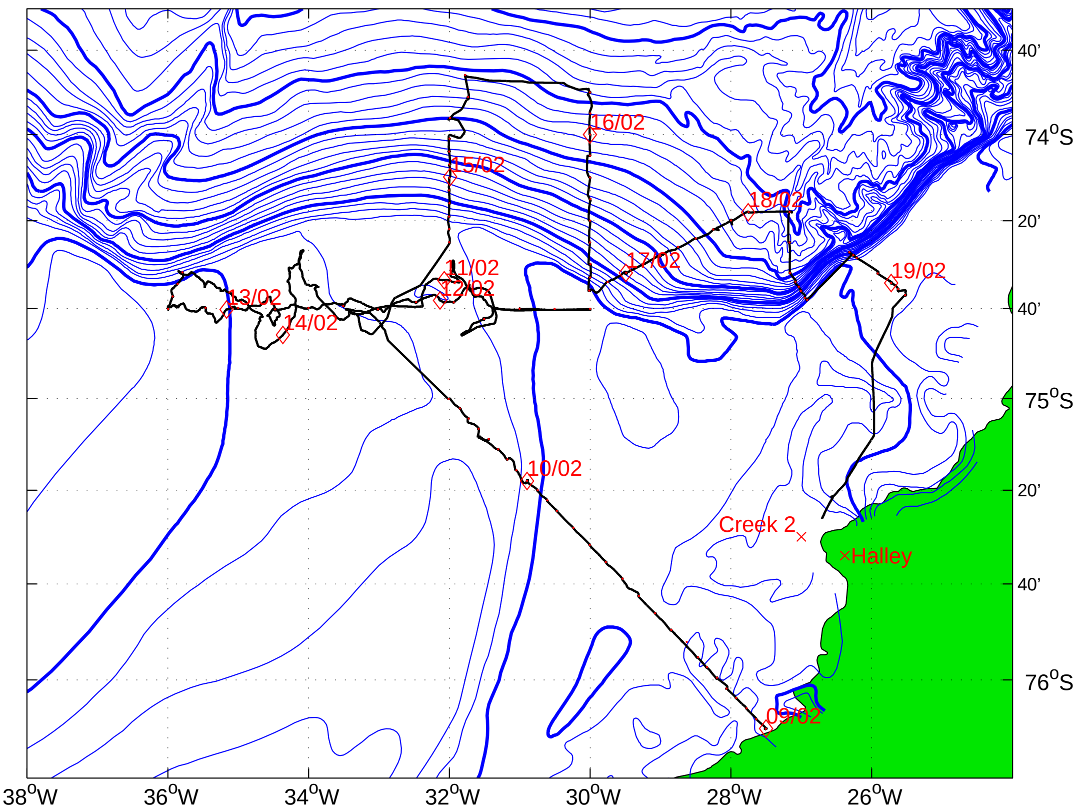

Fig. 1c. The circuitous route of the RRS Shackleton during the science cruise, from the start of CTD section 1 until returning to Creek 2. Times marked are midnight local time (GMT - 3).

We would like to thank the captain and crew of the RRS Shackleton for their invaluable assistance, and for making this cruise such a pleasant experience. This project was supported by the Norwegian Research Council as part of the Norwegian Antarctic Research Expedition 2001/2002, project no. 3545.

Section 1

After deploying the three BAS moorings around Halley, we proceeded to the start of the first CTD section, heading NW on a line from 76°10’ S 27°30’ W to 75° S 32° W. Station spacing was 3 nm between stations 1-9 and 17-28 and 5 nm between stations 9-17.

At the beginning of the first station, the CTD did not function properly, giving occasional random values of depth, temperature, and salinity, and sometimes stopping entirely with an error message about “record shorter than expected.” In addition, the bottom sensor was beeping intermittently. The first problem was finally narrowed down to a faulty serial cable between the PC and the deck unit. When the modem and data cables were switched, the CTD functioned properly. However, as the bottom sensor still was not working consistently, it was removed. To reduce the number of potential problems, we decided not to use the LADCP on the first section, where strong bottom currents were not expected.

On station 20 the CTD stopped working again. The problem was narrowed down to a short circuit in the termination on the sea cable. The instructions provided by UNIS said to solder the end connector onto a single strand of the sea cable shield. However, possibly due to inadequate insulation, this single strand burned its way through the insulation around the center core, and short circuited when flexed. It is likely that it had arced under high voltage. After re-terminating the sea cable, we proceeded with the section and did not encounter any further problems on this section.

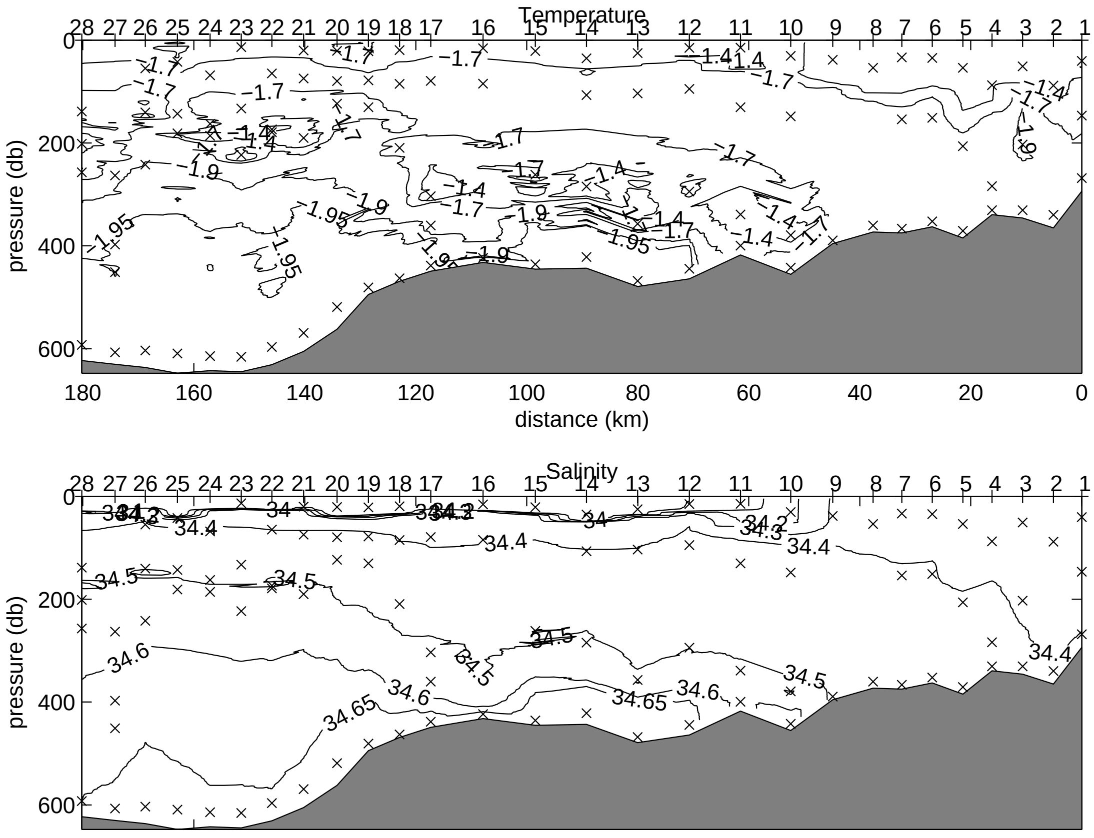

Fig. 2. Contour plot of temperatures and salinities on section 1. Water samples are marked with x’s.

Figure 2 shows the temperatures and salinities measured on the section. On the first nine stations we can see a warm, saline coastal current in the upper 100 meters. After these stations we observe melt water in the upper 30-40 meters, with temperatures around –1.6°C and salinities < 34. There appears to be a belt of warmer water stretching from the bottom near station 10, up to 150-250 meters' depth at stns. 21-24. It has T > –1.6°C and S≈34.5, and we believe that this is Modified Warm Deep Water (MWDW). Above this layer we observe water with T≈-1.8°C and S ≈34.4, which matches the description of Winter Water (WW) or Eastern Shelf Water (ESW). These two terms appear to be used interchangeably, and will henceforth only be denoted ESW. Beneath the belt of MWDW is a water mass with T<-1.9 and S≥34.55. This appears to be ISW flowing northward through the Filchner Depression.
The various water masses are shown in a θ-S diagram in fig. 3.

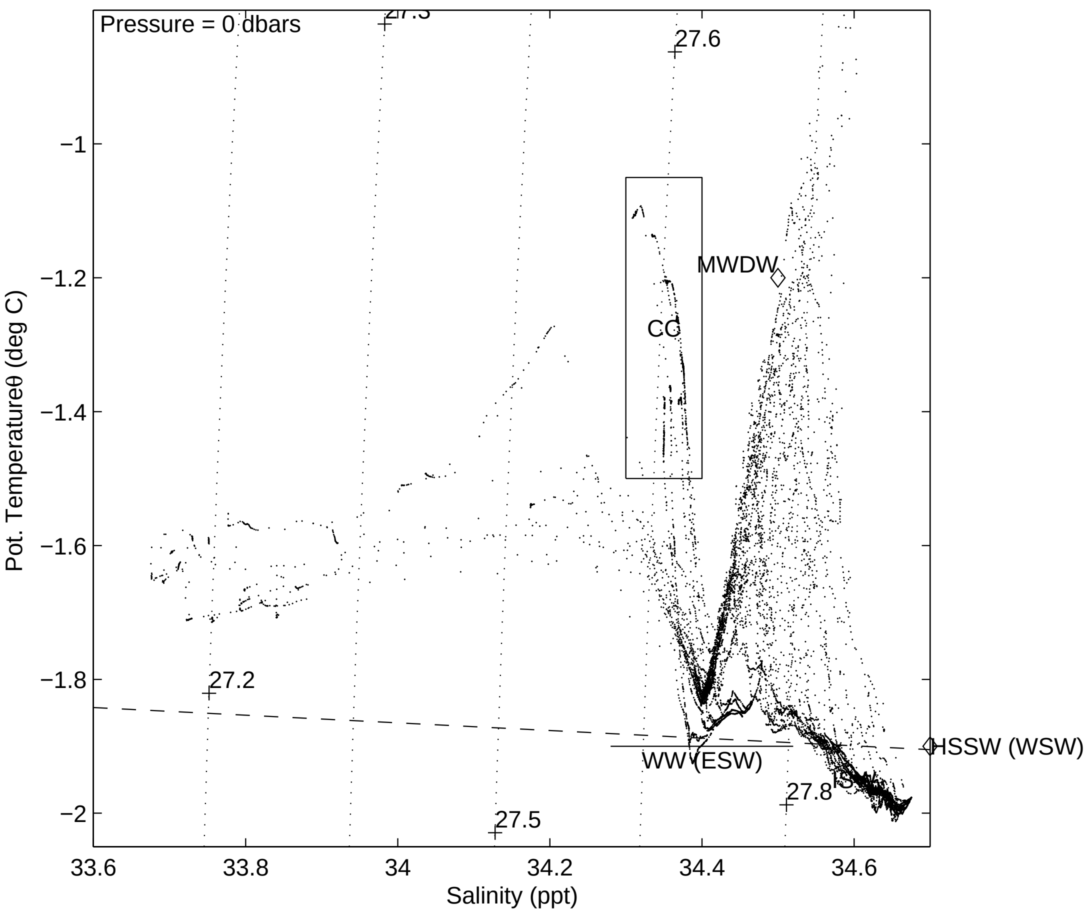

Fig. 3. θ-S diagram from section 1. Water mass definitions correspond to those of Foster and Carmack 1976 and Foldvik et al 1985, except for the Coastal Current (CC).

Section 2

Section 2 runs westward along 74°40'S from 30°W to 36°W, with stations every 30 min. longitude. The first station is slightly NE of the end of section 1, and we can see the very last trace of the coastal current on the first station. Again we see the layer of MWDW on stations 31-41, but here the MWDW is warmer than in the previous section, possibly because it is further north.

The LADCP was used on all stations, but an initial look at the data does not appear to make much sense. There is a core of northward-flowing water near the bottom of station 36, but there are also strong southward currents around stations 29-31 and 38. One possibility is that we are picking up tidal oscillations, but the period does not appear to fit any tidal cycle clearly.

The θ-S diagram again shows a clear presense of ISW, and apart from a warming of the MWDW, it does not differ much from the previous section.

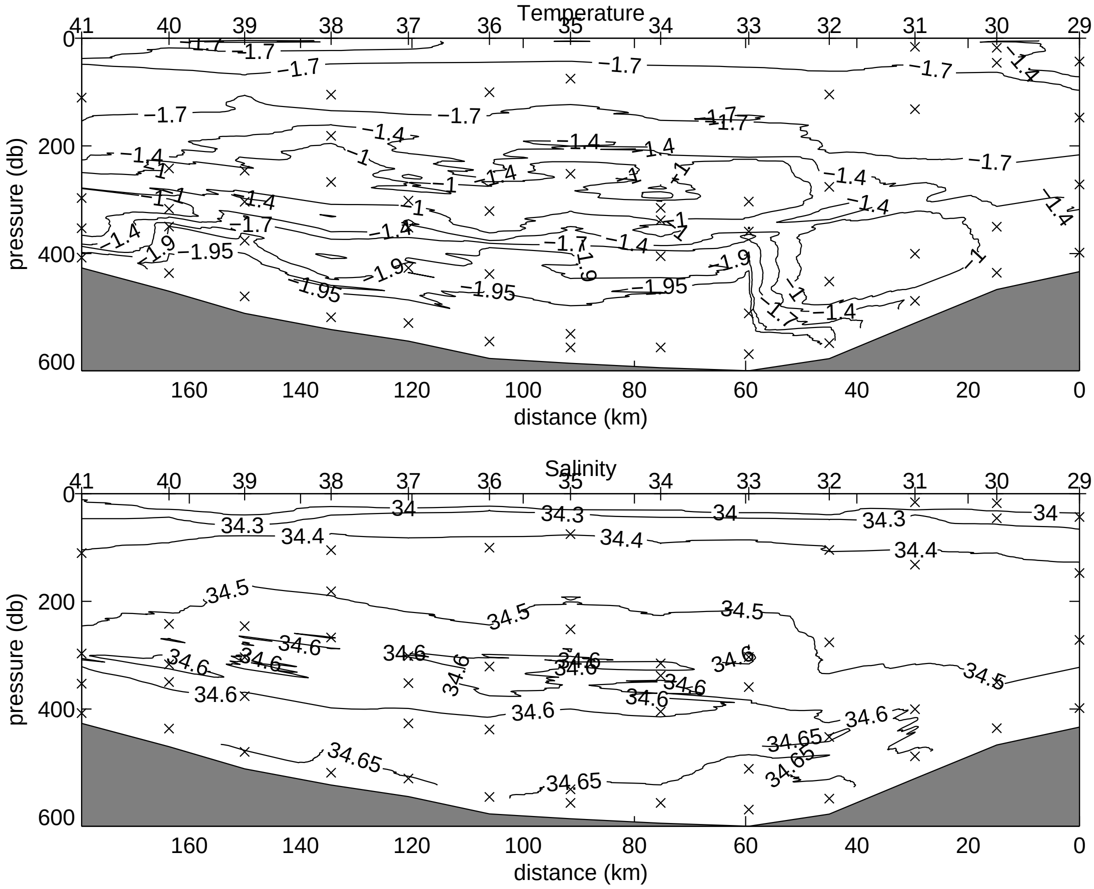

Fig. 4. Contour plot of temperatures and salinities on section 2. Water samples are marked with x's.

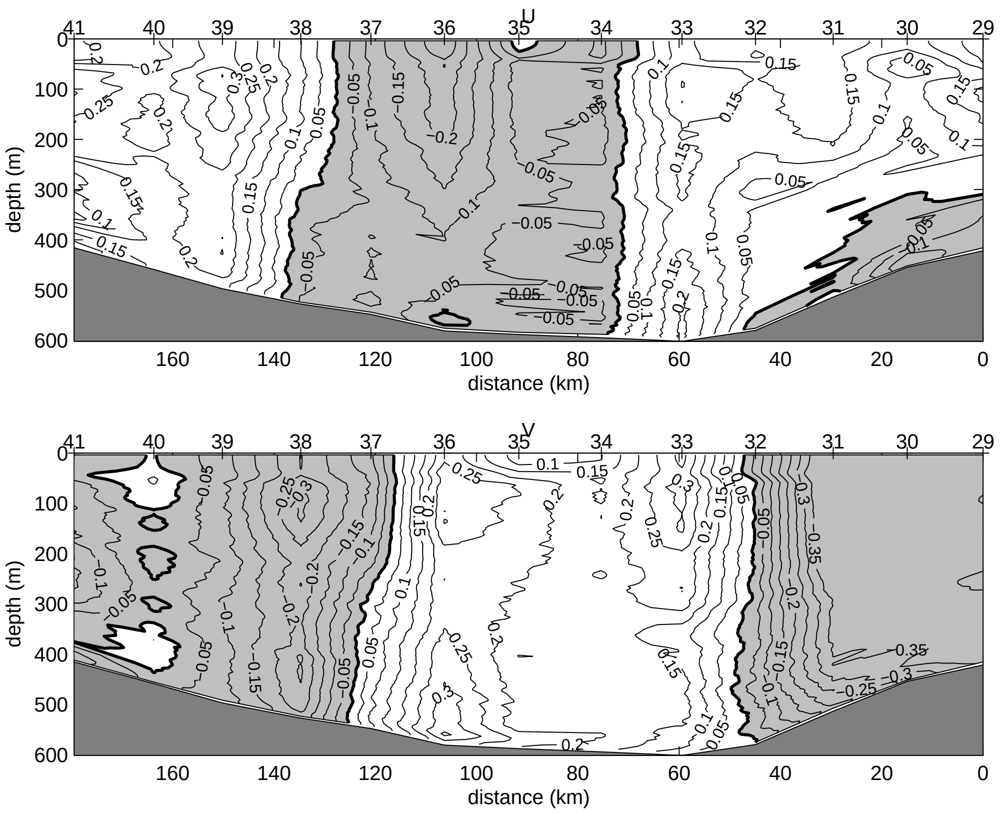

Fig. 5. Contour plot of LADCP velocities (in m/s) on section 2. Shaded areas represent negative values of u or v. The contour for 0 is bold.

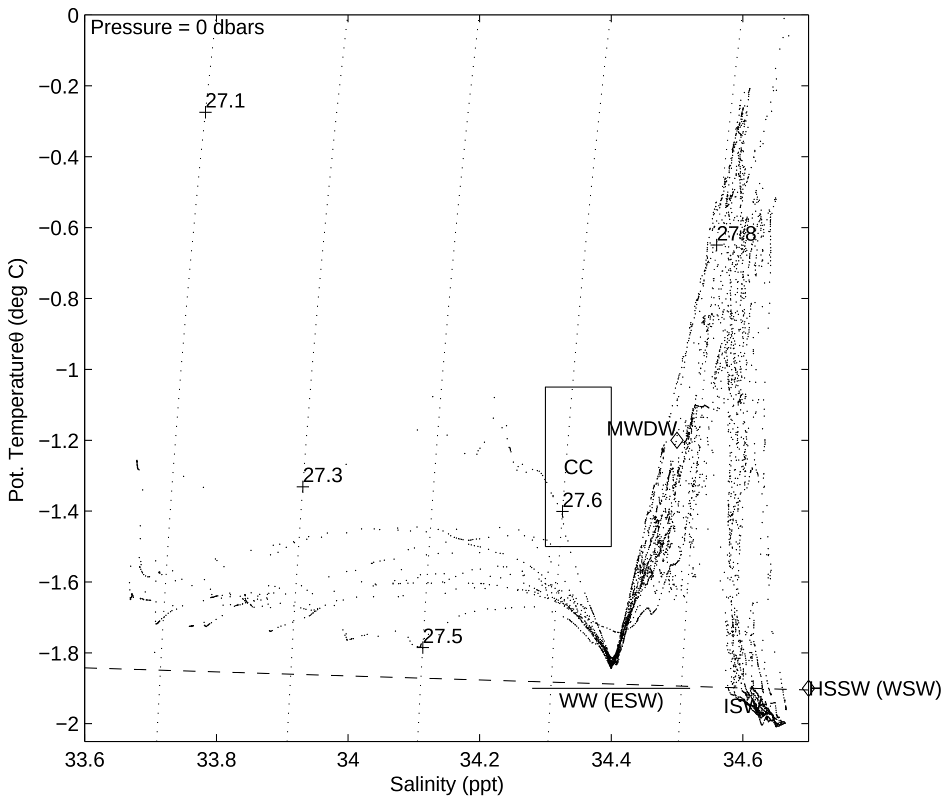

Fig. 6. θ-S diagram from section 2. Water mass definitions correspond to those of Foster and Carmack 1976 and Foldvik et al 1985, except for the Coastal Current (CC).

Section 3

Section 3 was a relatively brief attempt to continue NNE from the end of section 2. However, due to the ice conditions, we were forced to abandon it after only three stations. All of them used the LADCP. Although, unfortunately, this section is quite short, it does show some important differences from the previous sections. Most importantly, we note the higher temperatures in the warm layer, which now falls into Foster & Carmack's definition of WDW. Also note that the strongest currents are found just below this layer at the bottom of station 44.

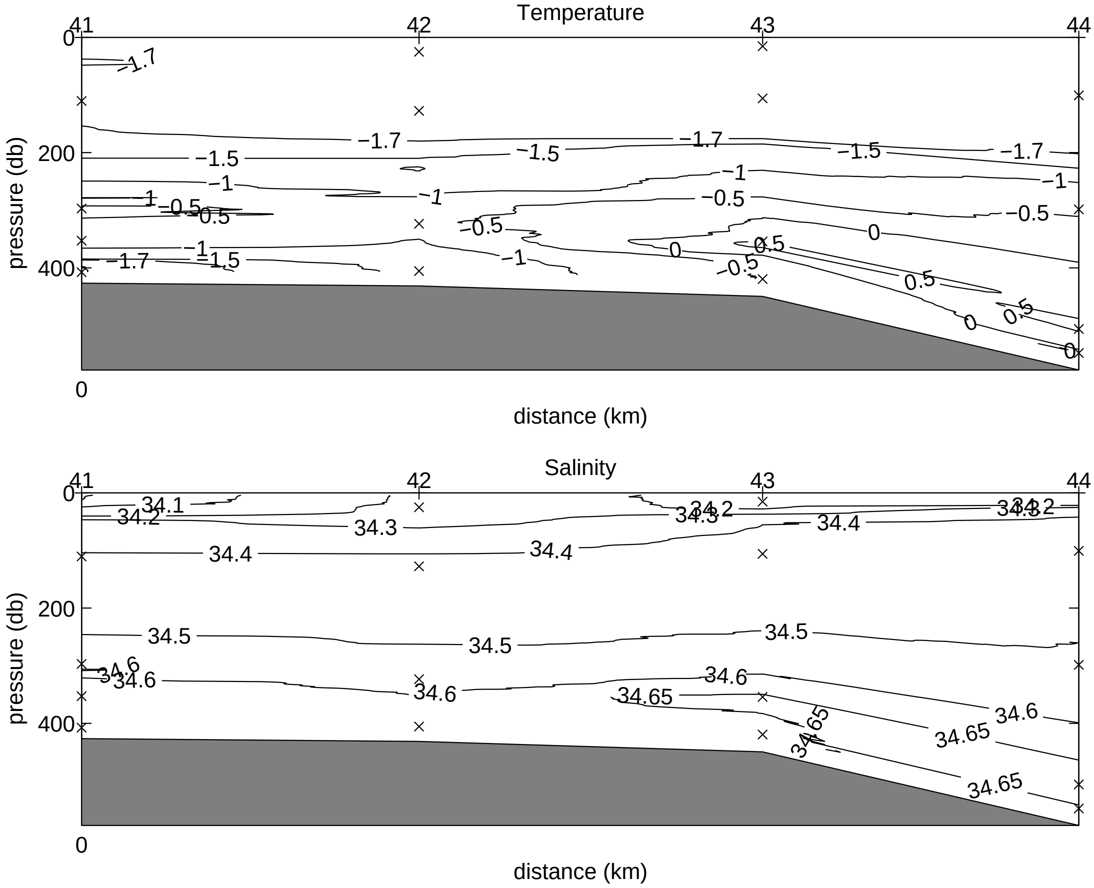

Fig. 7. Contour plot of temperatures and salinities on section 3. Water samples are marked with x's.

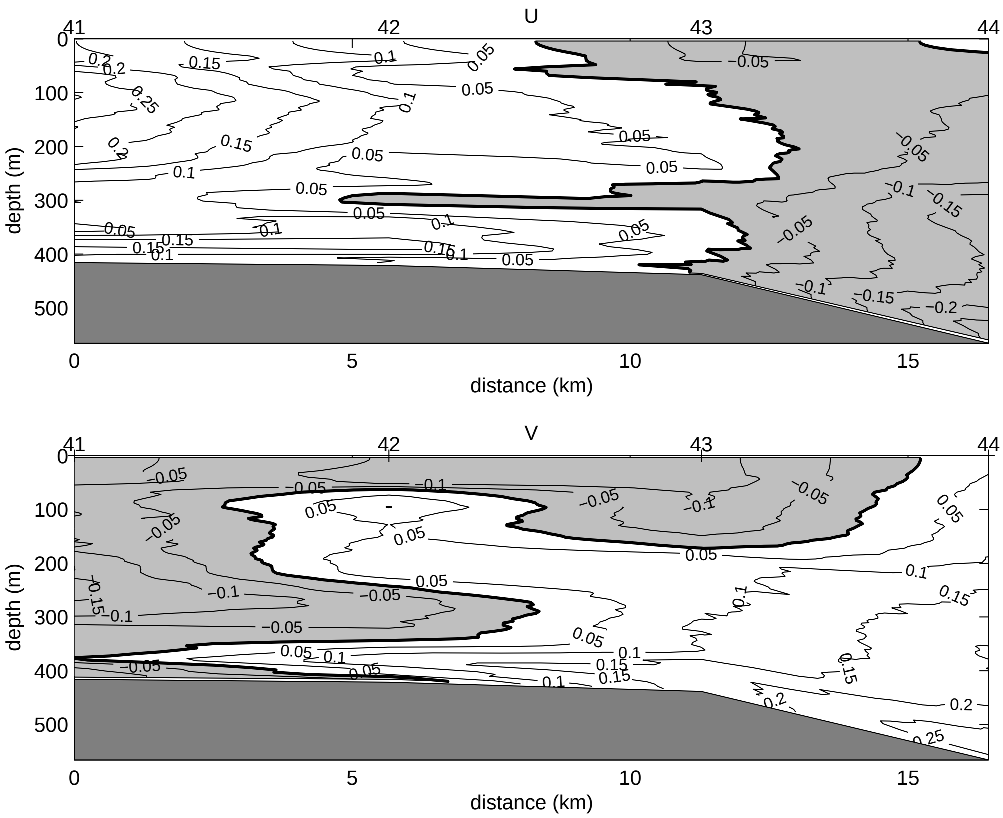

Fig. 8. Contour plot of LADCP velocities (in m/s) on section 3. Shaded areas represent negative values of u or v. The contour for 0 is bold.

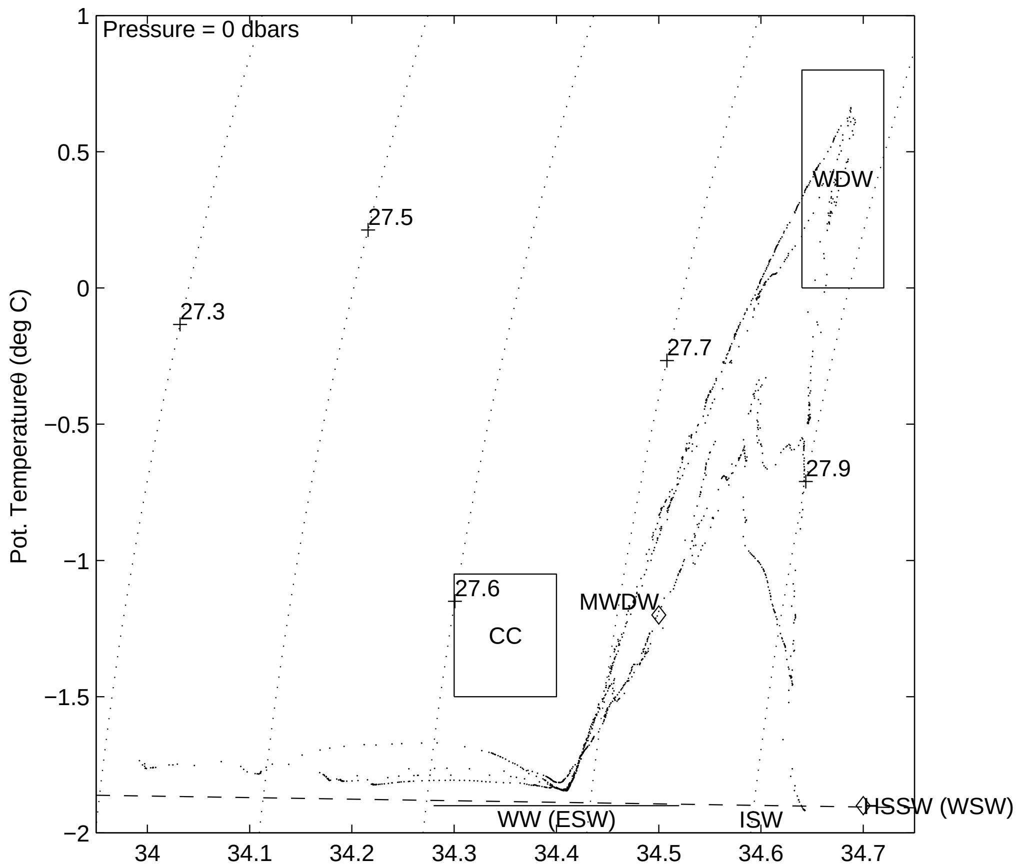

Fig. 9. Fig. 6. θ-S diagram from section 3.

Section 4

After another failed attempt to sail north at 34°W, we continued to 32°W, where we took our fourth section. Here, we managed to take a total of 12 stations, of which the LADCP was used on the first four. This may be the most interesting section taken, as we found an unidentified plume-like structure on some of the stations, at a much greater depth than expected.

On the first two, possibly three, stations we see ISW at the bottom. From the LADCP, we can see that the current is rather weak at the first station, while the next two have a slightly stronger bottom current toward NW. There is an extremely well-mixed uniform ESW layer in the upper 600 meters, and WDW below. From station 50 onwards, the temperature of the WDW core is above +0.5 °C and the salinity exceeds 34.7. In the layer between ESW and WDW, there are obvious “steps” in the temperature on some profiles. Also, in many stations there were significant differences between downcasts and upcasts, indicating the presence of internal waves. But the most interesting features are near the bottom. Fig. 12 shows the bottom temperatures and salinities. There is a colder, slightly fresher layer of water just above the bottom on stations 49-51, less clear in stns. 52-53, but pronounced at stn. 54 and slightly less so on stn. 55. Fig. 12b shows potential temperature, salinity, and potential density γ referenced to the bottom pressure (2013 dbar) for stn. 54. The presence of a density-driven bottom plume is clearly indicated. From the θ-S diagram in fig. 13, we can see that this appears to be a mixture between WDW and an unidentified water mass, possibly ISW. It is unexpected, to say the least, to find a plume like this at this depth, so far east. A possible explanation is the presence of a canyon further east, allowing ISW to flow down a narrow channel and then follow the isobaths westward. A detailed analysis of the ship’s echo sounder data reveals no such canyon, but a more detailed survey of the shelf area could certainly be desired, preferably using side-scan sonar.

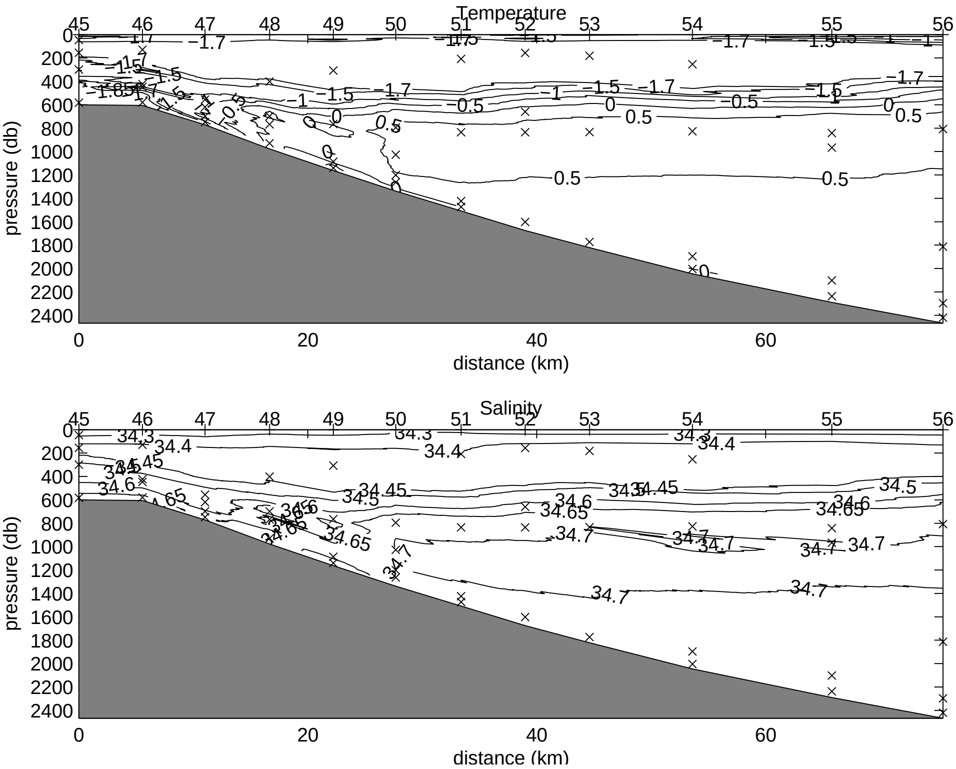

Fig. 10. Contour plot of temperatures and salinities on section 4. Water samples are marked with x’s.

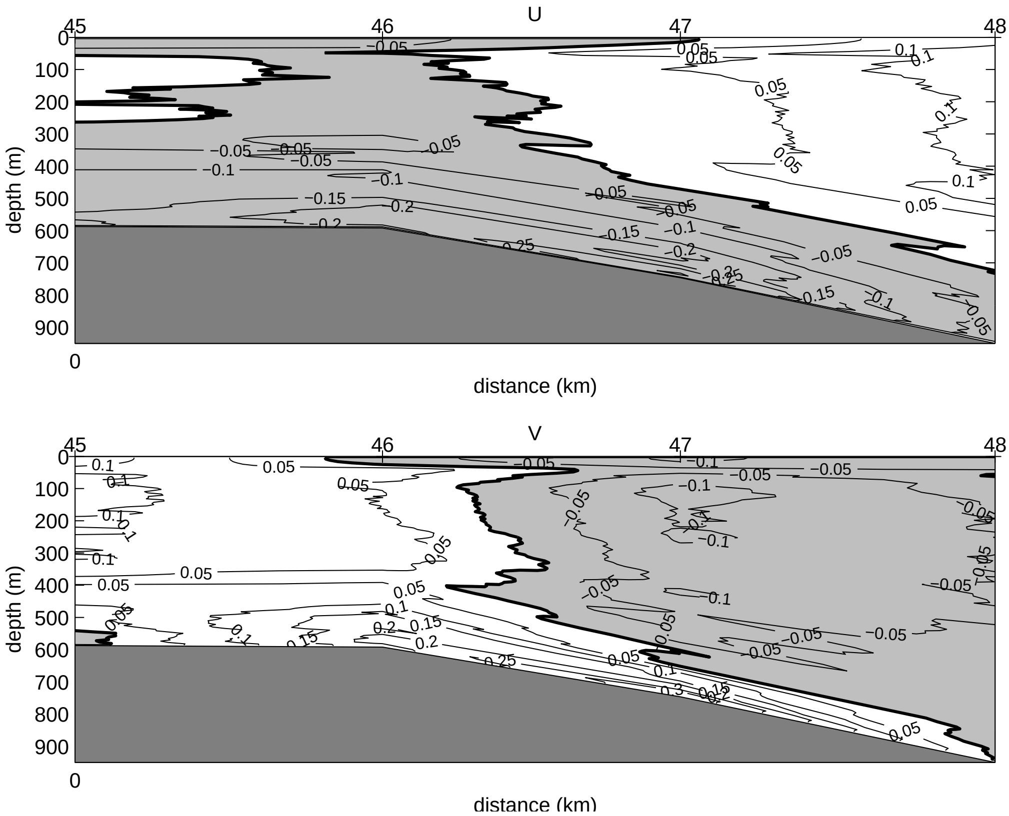

Fig. 11. Contour plot of LADCP velocities (in m/s) on section 4. Shaded areas represent negative values of u or v. The contour for 0 is bold.

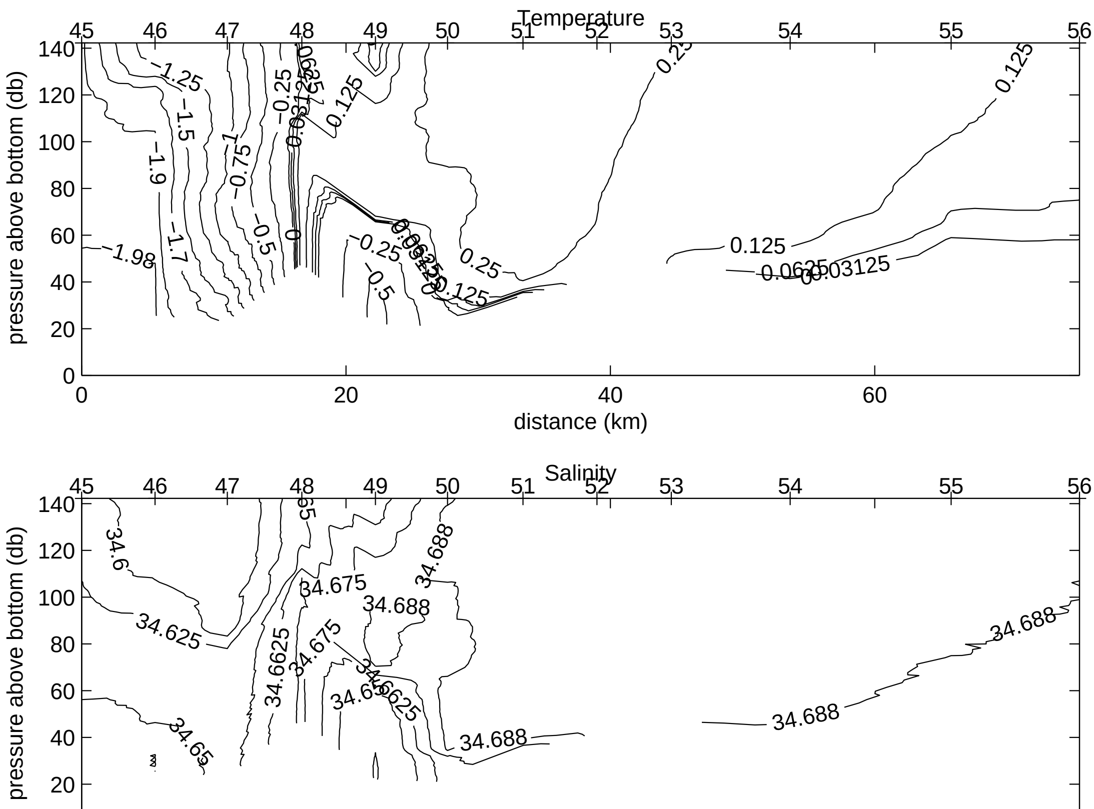

Fig. 12. Contour plot of temperatures and salinities near the bottom of section 4.

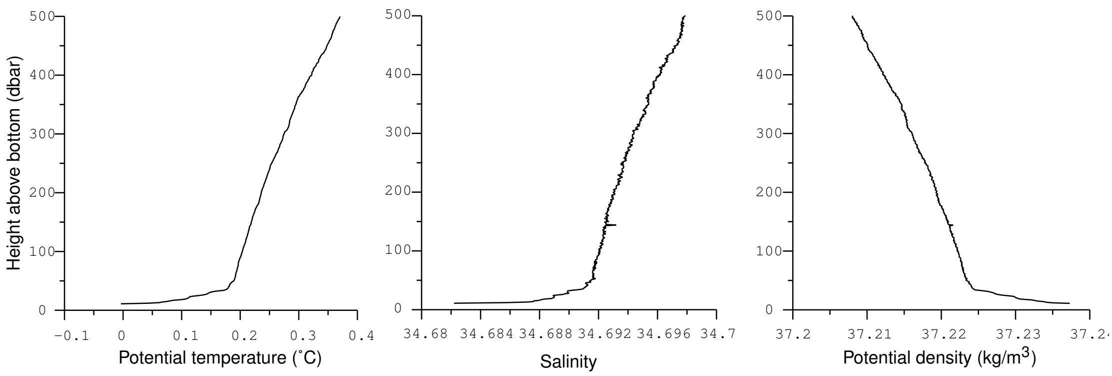

Fig. 12b. Profiles of potential temperature, salinity, and potential density γ referenced to the bottom pressure (2013 dbar) for the deepest 500 dbar of station 54.

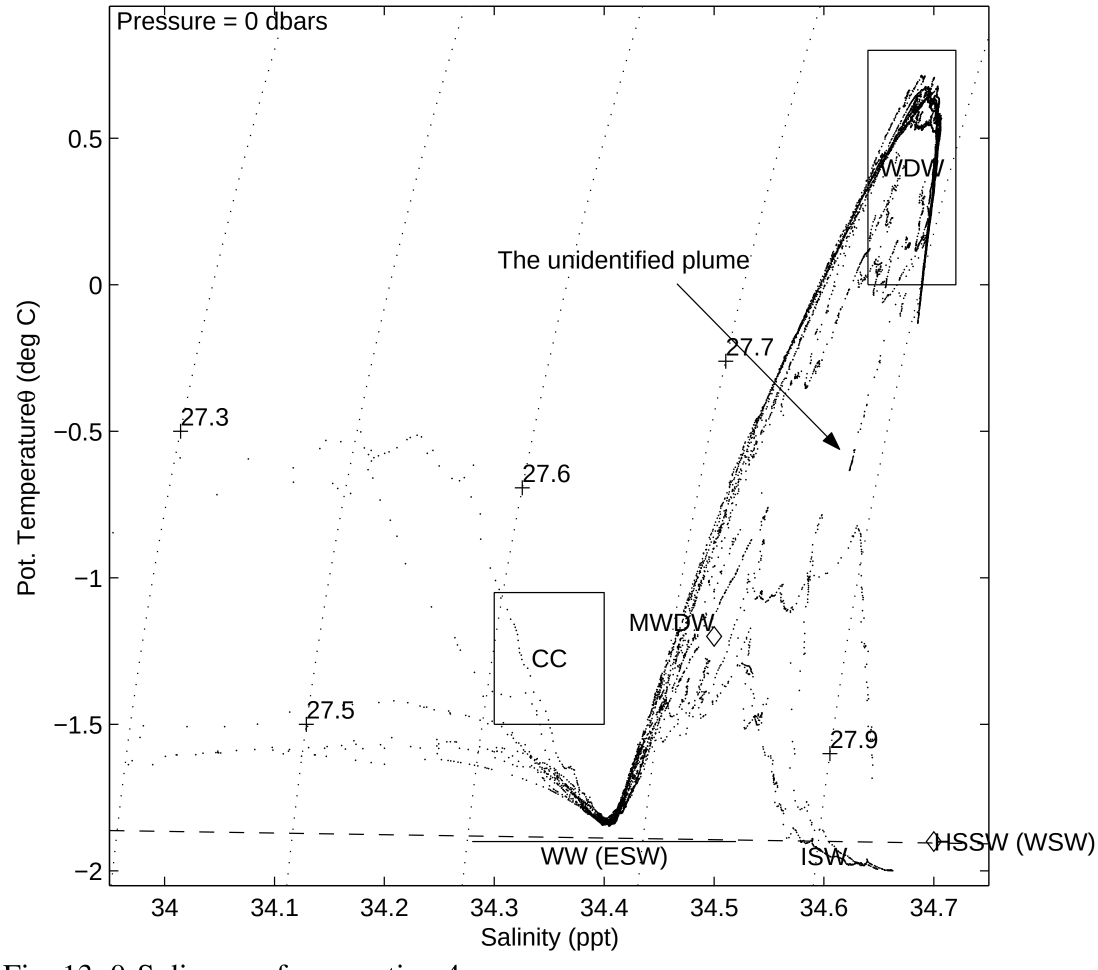

Fig. 13. θ-S diagram from section 4.

Section 5

After completing section 4, we proceeded E to 30°W, where we took a profile south onto the shelf. Station spacing was 5 miles, and the LADCP was used on the three last stations. Unfortunately, the LADCP file from station 66 appears to have started after the CTD was in the water; hence it cannot be correctly processed. The same is the case with station 68, on section 6.

This section is relatively similar to the previous in terms of general hydrography. However, we do not observe the plume at 1000-1500 m depth, but do note a much less extreme, but still possibly significant fall in temperature and salinity, with a corresponding rise in density, on the first two stations. This may be a trace of a similar water mass, implying that the source may lie further east. However, as our stations do not show where this water mass ends, we are not quite sure whether this in fact is a weak plume, or the trace of a plume.

On the LADCP profile, we can see that the currents are extremely low on most of station 65, and slightly higher towards SE on the upper part of stn. 67. The lower layer in both stations shows a weak current towards NW.

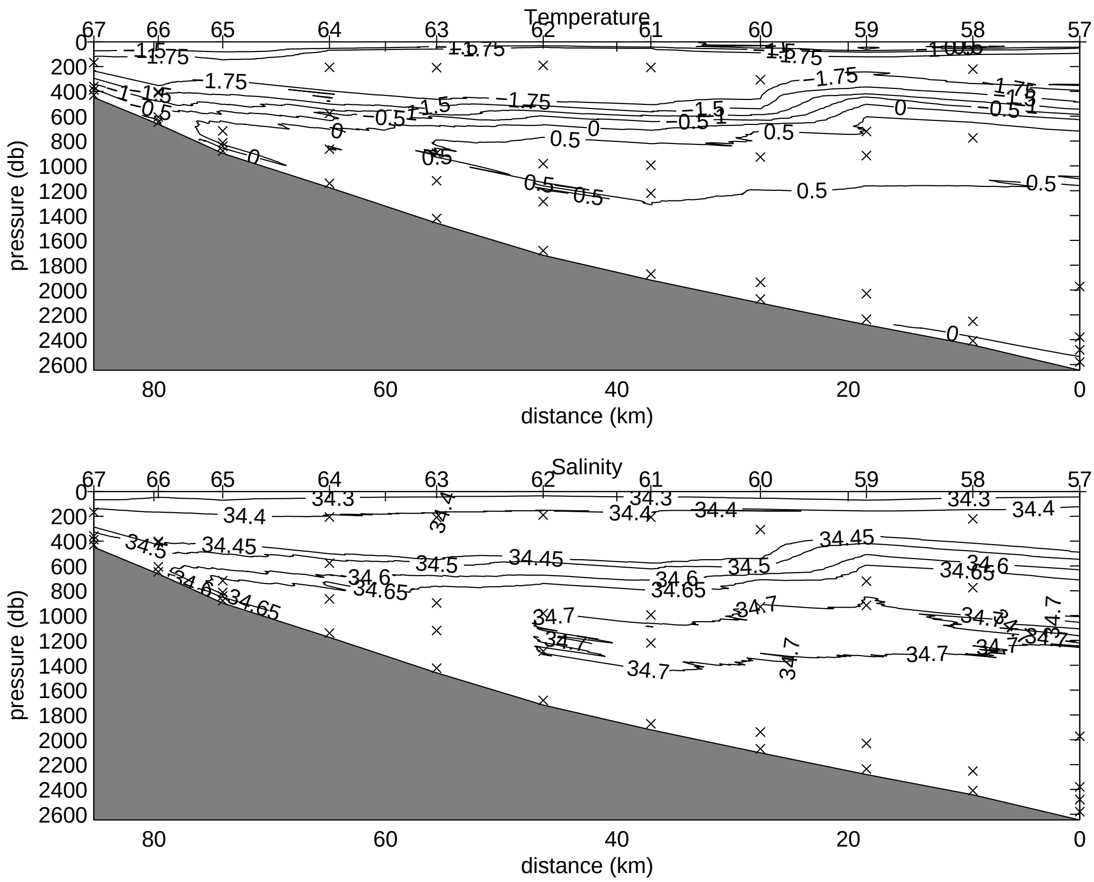

Fig. 14. Contour plot of temperatures and salinities on section 5. Water samples are marked with x's.

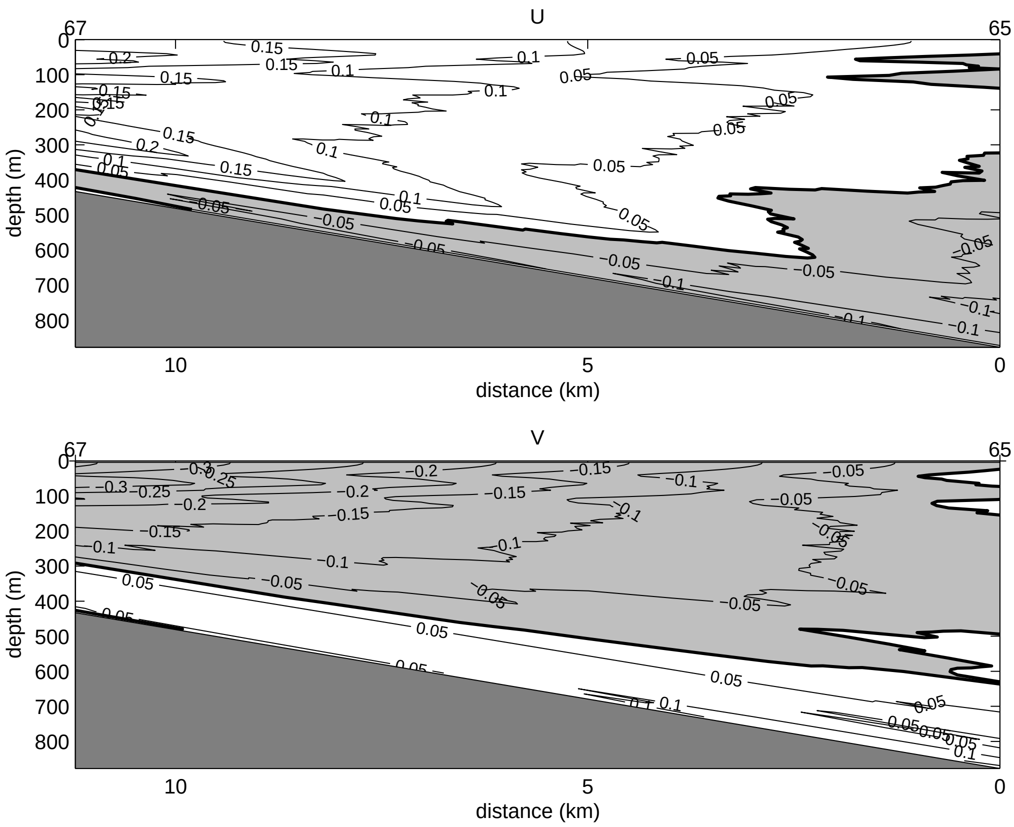

Fig. 15. Contour plot of LADCP velocities (in m/s) on section 5. Shaded areas represent negative values of u or v. The contour for 0 is bold.

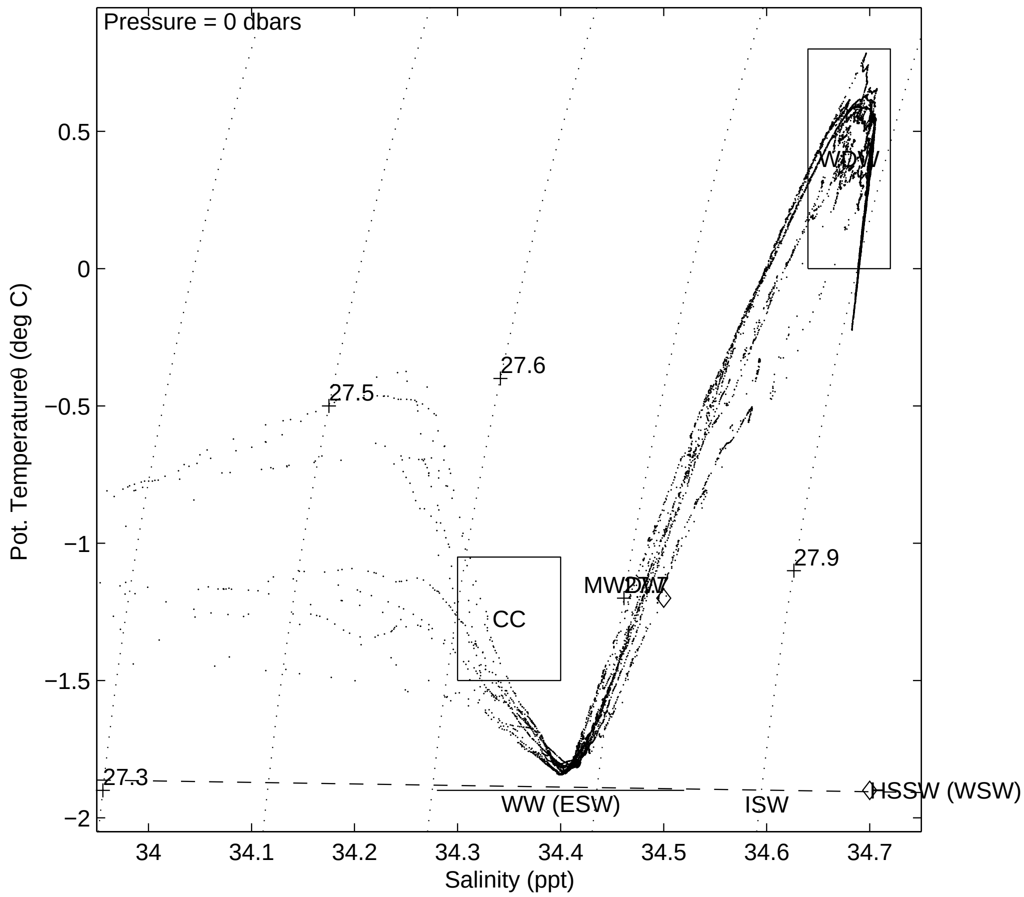

Fig. 16. θ-S diagram from section 5.

Section 6

Section 6 continues from the end of section 5, heading NE, with a slight break due E into a canyon for station 77. The LADCP was used on the first station, but did not produce a valid profile. On station 68, the correct depth, as identified by bottom tracking on the ADCP, was in fact 769 m and not 795 m, as the ship's echo sounder led us to believe, and we have reason to believe that the CTD hit the bottom. Upon retrieval, a large knot appeared on the cable, and after recovering the CTD, it was re-terminated. When re-taking the station, the sea cable suddenly short circuited. One hypothesis of what occurred, was that a bit of sea-water entered the connector, causing a short circuit, and making the bulkhead connector overheat and thereby damage its insulation, This, in turn, caused the sea cable to overheat and arc when re-connected. After replacing the bulk-head connector (but not the sea cable connector), the CTD functioned until station 75, when an inspection showed that both the bulkhead connector and the sea cable connector had been damaged, and arced when high voltage was applied. After replacing both connectors with scavenged parts, the CTD functioned properly for the remainder of the cruise, but station 75 was not re-taken.

This section is very similar to the previous one.

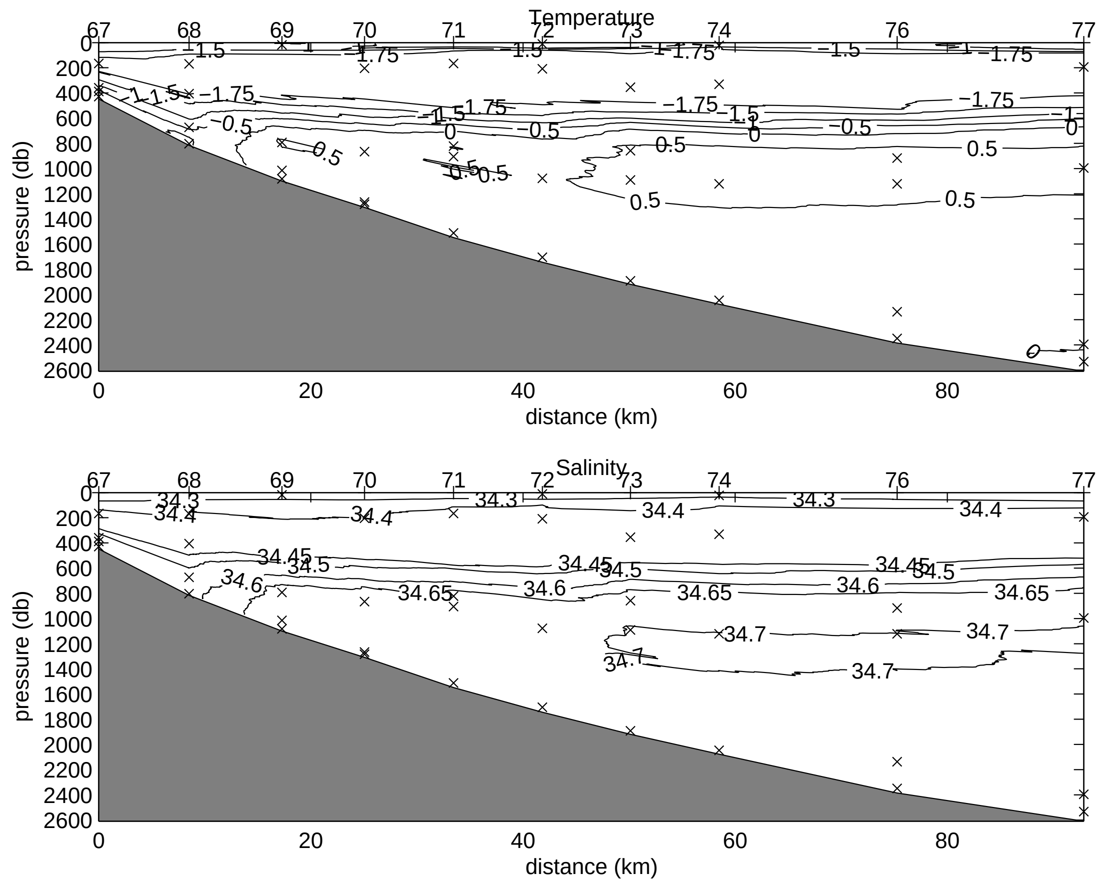

Fig. 17. Contour plot of temperatures and salinities on section 6. Water samples are marked with x's.

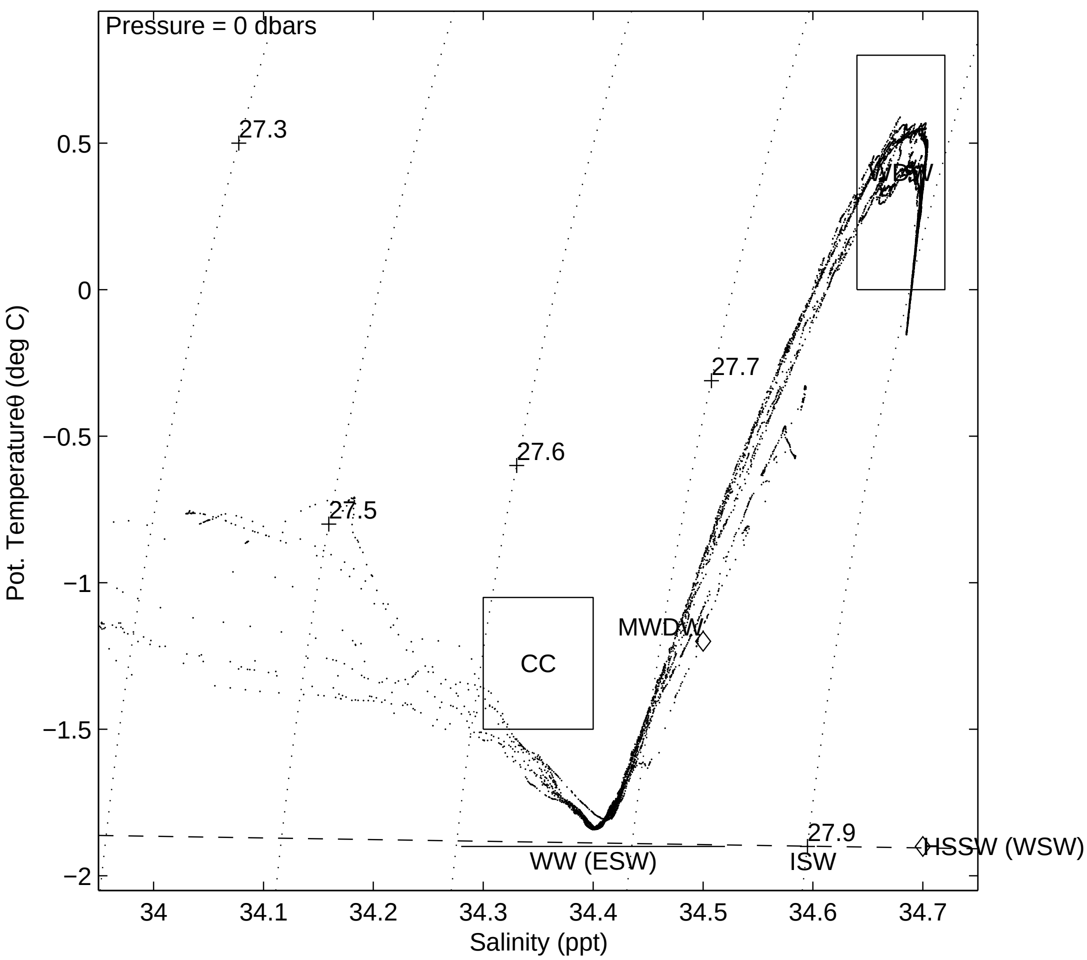

Fig. 18. θ-S diagram from section 6.

Section 7

The penultimate section of the cruise was taken from the canyon of stn. 77 towards Halley, starting off with a course due S, and then turning SSE after stn. 79. The LADCP was used on the two last stations.

There are not any particular changes in hydrography from the previous section; however, due to the closer station spacing on the slope, we can see the end of the WDW/MWDW layer much more clearly.

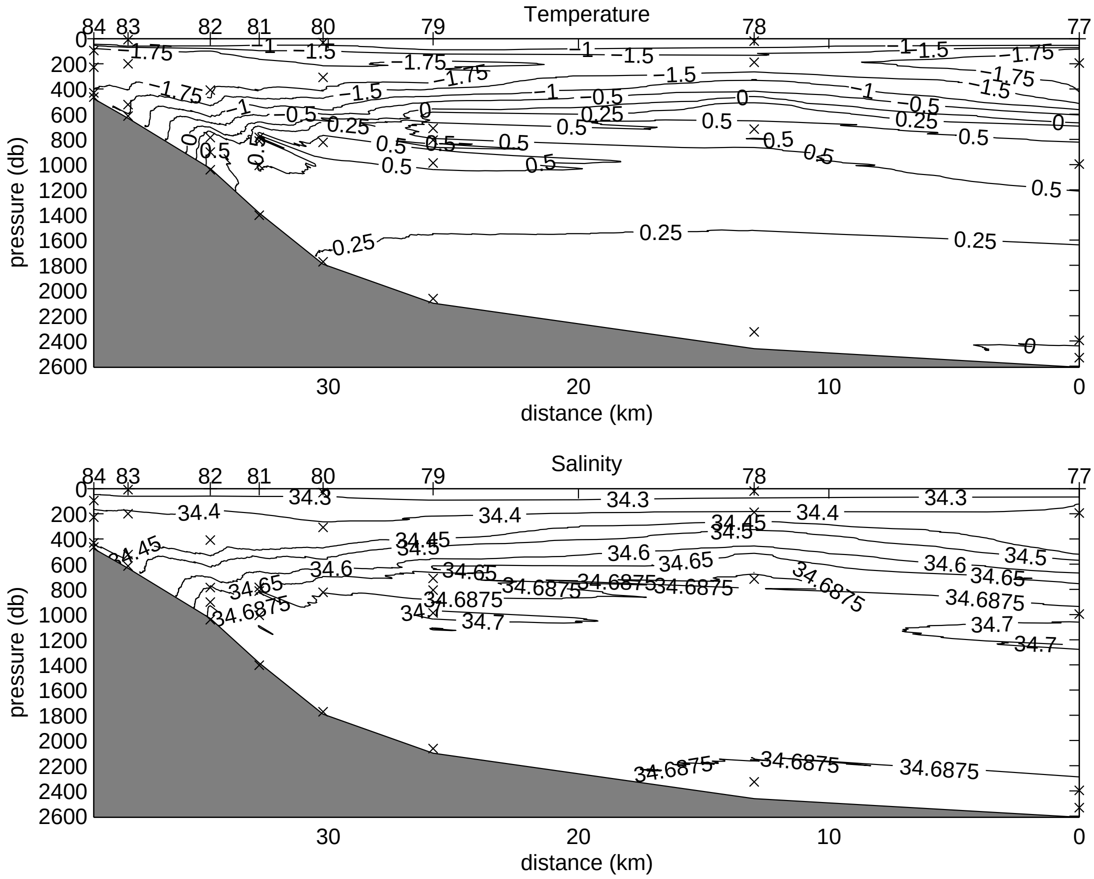

Fig. 19. Contour plot of temperatures and salinities on section 7. Water samples are marked with x's.

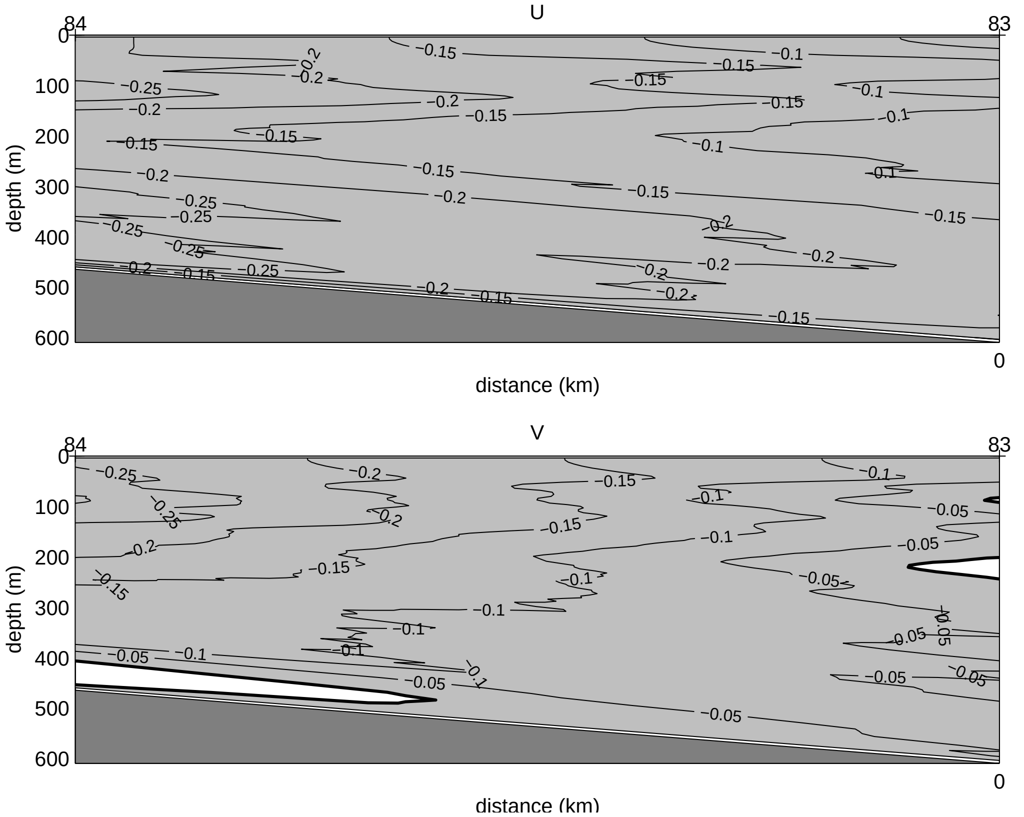

Fig. 20. Contour plot of LADCP velocities (in m/s) on section 7. Shaded areas represent negative values of u or v. The contour for 0 is bold.

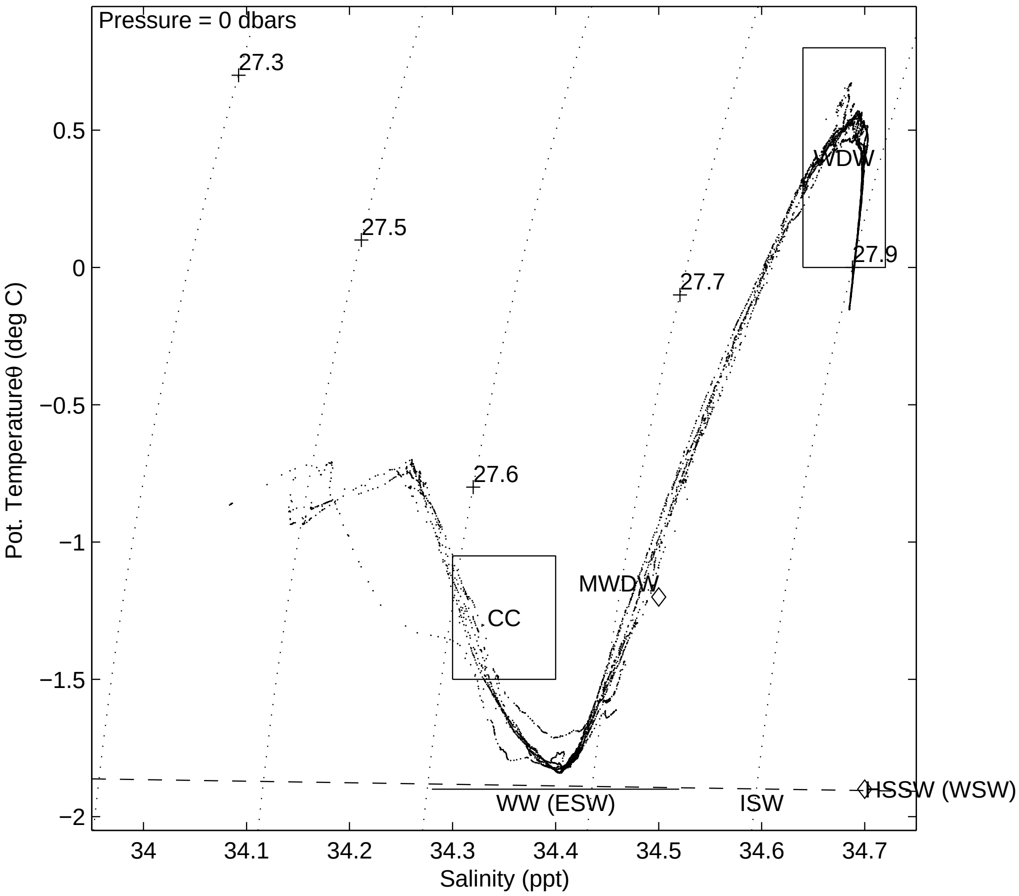

Fig. 21. θ-S diagram from section 7.

Section 8

Section 8 was taken from a position further E, on a straight line towards the ice shelf. Initially, station spacing was based on depths, so we have stations at 1000, 800, and 600 meters, and after that they were apparently spaced quite randomly. The final planned station was in the ice (the coastline on our map was quite outdated), so the station was placed as close as conditions would allow. Towards the end of this section, weather was worsening considerably, and the swell may have influenced LADCP measurements; the tilt measurements indicate shaking, especially on the downcast.

Note that on profile 90 the CTD was only lowered to 450 meters, while the correct depth was closer to 550. This was probably due to a communications error between the bridge and the CTD caboose. The LADCP indicates a depth of 570 m here.

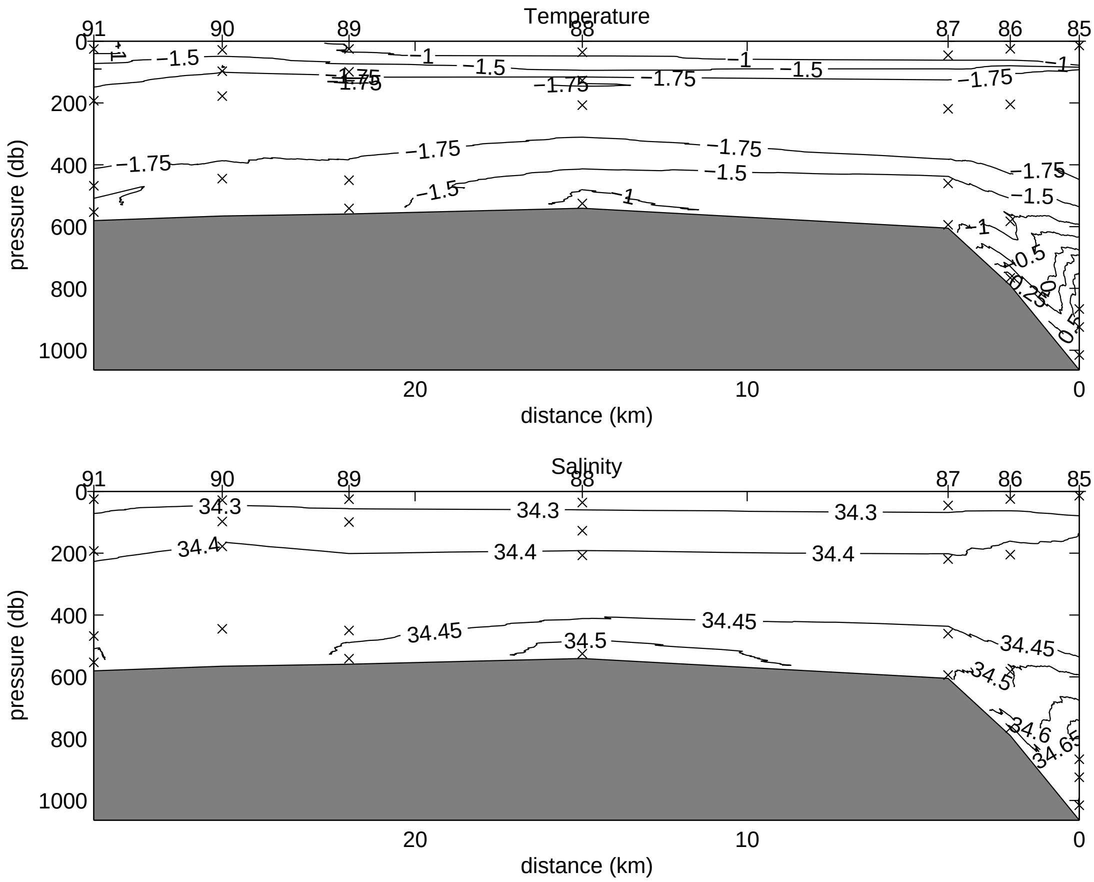

Fig. 22. Contour plot of temperatures and salinities on section 8. Water samples are marked with x's.

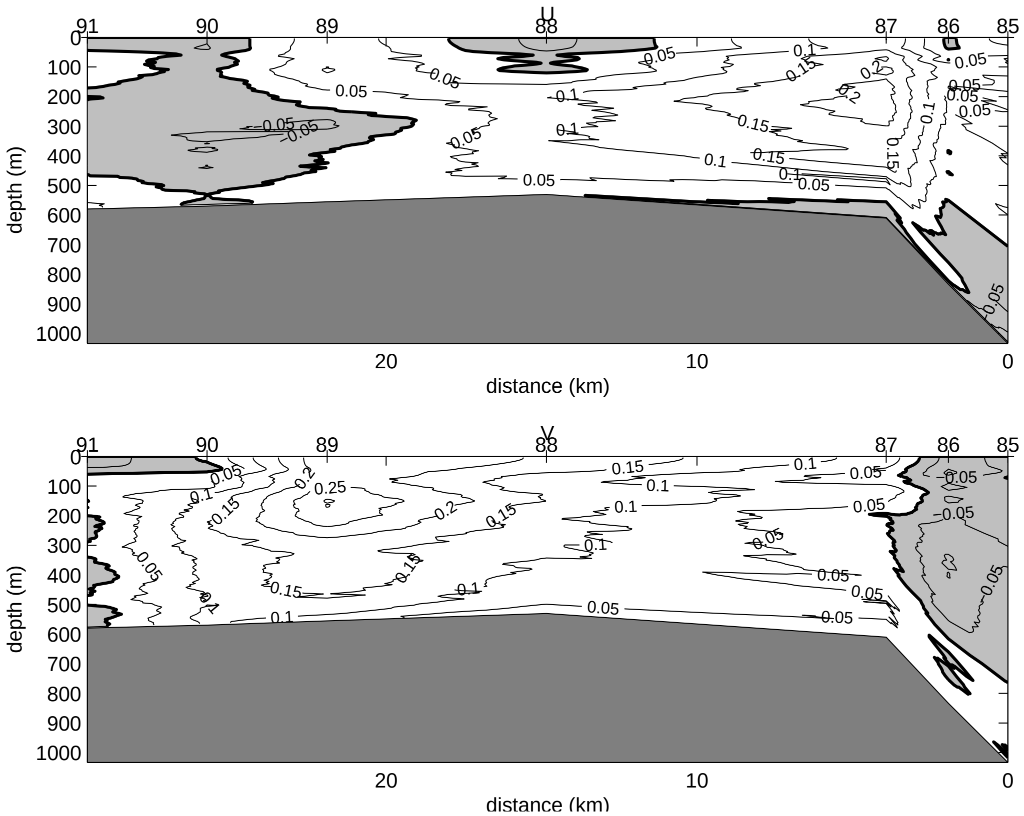

Fig. 23. Contour plot of LADCP velocities (in m/s) on section 8. Shaded areas represent negative values of u or v. The contour for 0 is bold.

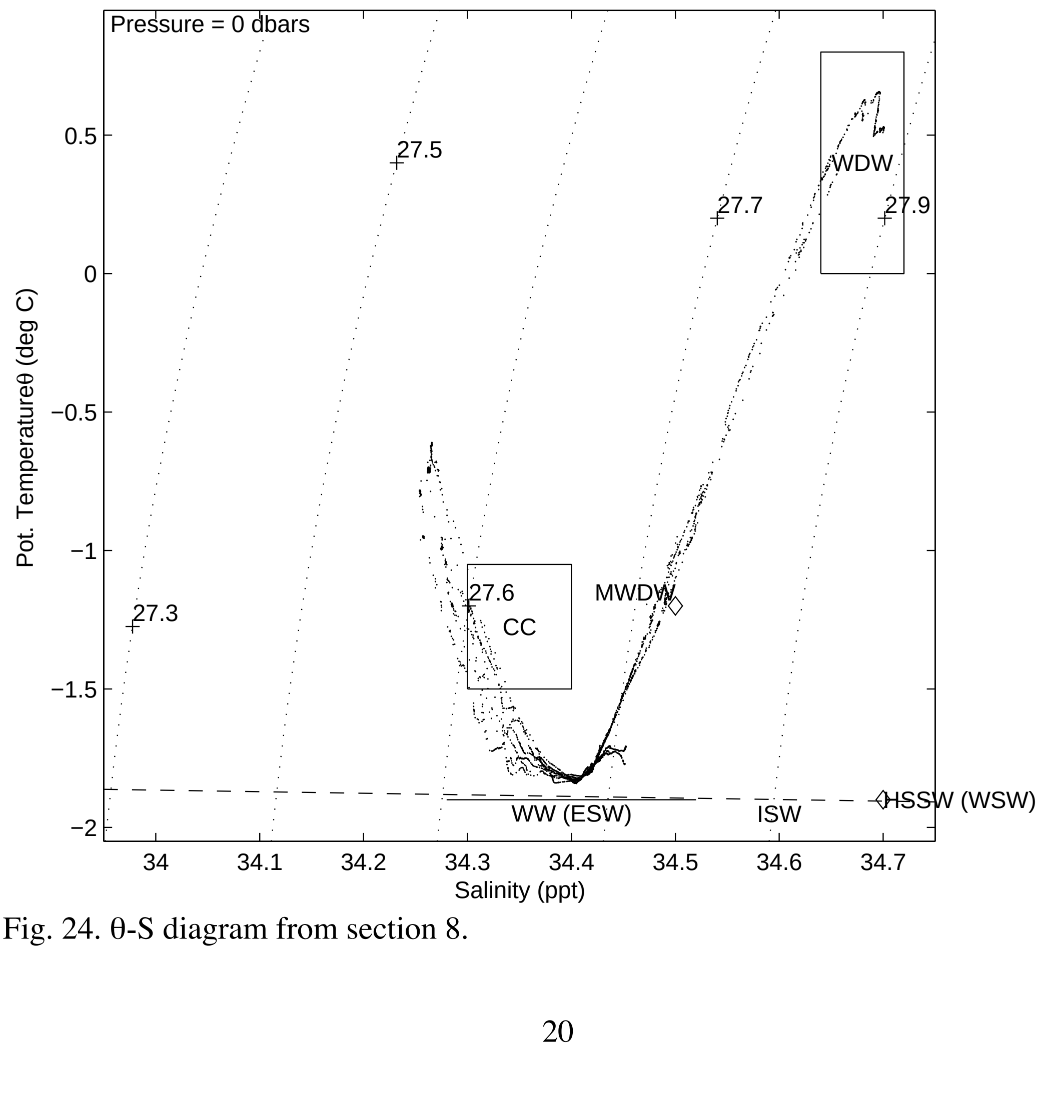

Fig. 24. θ-S diagram from section 8.

A little note on topography

As we did find what appears to be a plume in a rather unexpected place, we would like to investigate the topography of the area closer. The ship's SIMRAD EA500 echo sounder recorded continuously, and we have received a file containing these data along with GPS positions for the duration of the cruise. All these files use the ship's time, which is GMT –3 hours; the files have a record for every second, with quite frequent and easily removed invalid GPS points. In an attempt to compare these data to the GEBCO data set, GEBCO was gridded on a 5x1.25-minute grid in the area. The ship's depth records were then first-order corrected for sound speed variations, using spatially interpolated depth-integrated sound speeds from the CTDs. It is interesting to note that the depth-averaged speed of sound on stations varies between 1442.79-1469.36 m/s, with a std. dev. of 8.41 m/s. The mean of the ship's depth records within each cell was then subtracted, and a smooth surface going through all these points, and going to zero at the edges, was created. This surface was then added to the GEBCO data set, to generate a new topography, correcting GEBCO to the ship's data. The resulting data set is shown below. Any jagged edges are probably due to Matlab's contour plot system. Compared to fig. 1c, we note that there are not too many differences. A similar procedure was followed using the 5x5-minute NCAR TerrainBase topography, but the differences were significantly larger, indicating that GEBCO's bathymetry is much better in this region.

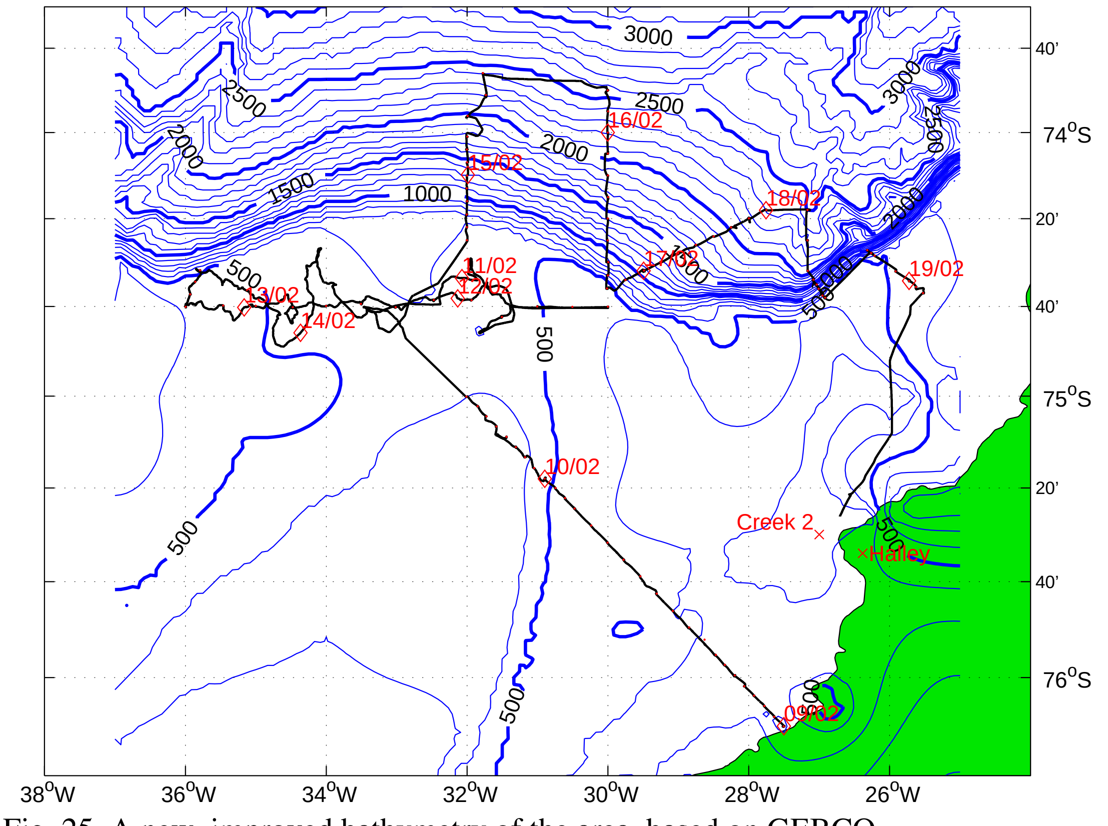

Fig. 25. A new, improved bathymetry of the area, based on GEBCO.

Appendix A: Log for the GIANTS-RISOC project on RRS Ernest Shackleton Cruise February 2003 to the Weddell Sea

2003 01 22	Changed batteries in the two Bergen acoustic releases and checked that they functioned properly.
2003 02 03 13:40 GMT	Started all 9 BAS current meters. Before that, all the DSUs had been erased, their clocks adjusted where necessary (GMT). Current meters switches had been checked and adjusted where necessary.
2003 02 03 14:40 GMT	All 9 BAS current meters had their second triggering.
2003 02 03 21:00 GMT	Started 2 Bergen current meters after DSUs had been erased and clocks set (GMT):
	RCM9 s.n. 195: T-range=Arctic, Cond-range=0-74 mS, 8 channels, rec.-int.=60min
	RCM9 s.n. 630: T-range=Arctic, Cond-range=24-39 mS, 7 channels, rec.-int.=60min
2003 02 03 22:00 GMT	Both Bergen RCM9 current meters had their second triggering.
2003 02 04	All 3 BAS acoustic releases were tested and armed with releaser rings. Release functions worked successfully. Releases were give OFF command at end.
2003 02 05	Assembled BAS moorings B1 and B2 on deck.
2003 02 06 morning	Assembled BAS moorings B3 on deck.
2003 02 06 12:00 GMT	Started 1 Bergen current meter after DSU had been erased and clock set (GMT):
	RCM7 s.n. 67, DSU 12343: T-range=Low&Arctic, rec.-int.=120min
2003 02 06 14:00 GMT	Bergen RCM7 s.n. 67 current meter had its second triggering.
2003 02 06 17:11 GMT	Deployed BAS mooring B3, buoy first, at position (anchor) 75°48.734'S, 26°51.953'W, heading: 070°, distance to ice shelf: 2000m, echosounder depth: 329m, corrected bottom depth: 317m. After deployment, OFF command was sent to Acoustic release with response: 322. During the deployment, the rotor of the uppermost current meter, RCM7 s.n. 11676, broke. The current meter was hauled back onto deck and the rotor replaced. The lower rotor bearing was loose, but the new rotor appeared to function properly.
2003 02 06 18:41 GMT	Deployed BAS mooring B2, buoy first, at position (anchor) 75°43.268'S, 27°16.603'W, heading: 071°, distance to ice shelf: 2600m, echosounder depth: 301m, corrected bottom depth: 290m. After deployment, several OFF commands were sent to Acoustic release with irregular responses.
2003 02 07 17:22 GMT	Deployed BAS mooring B1, buoy first, at position (anchor) 75°27.911'S, 26°50.477'W, heading: 053°, distance to ice shelf: 900m, echosounder depth: 228m, corrected bottom depth: 220m. After deployment, OFF command was sent to Acoustic release with response: 225.
2003 02 08 24:00 GMT	Started CTD (without LADCP) station 1 on the first Track at 76°10'S, 27°30'W towards NW. Before this, a defective interface cable between the deck unit and the PC had been diagnosed and switched and the bottom contact had also been disconnected, due to irregular operation.
2003 02 09 20:10 GMT	The CTD stopped functioning during station 20. The reason was found to be a shortage, because the single strand from the seacable, which according to instructions should be soldered to one of the connector cables, had become too warm and had burned its way through the shielding of the core connector. This was repaired and station 20 was reoccupied.
2003 02 10 11:36 GMT	Started the last station, no. 28, on Track 1 at 75°S, 32°W. The LADCP was not used on any station on this section.
2003 02 10 19:12 GMT	Deployed Bergen mooring S2, buoy first, at position (anchor) 74°40.063'S, 33°27.649'W, echosounder depth: 596m, corrected bottom depth: 597m. After deployment, range command was sent to release (s.n. 758). There was no response, but this may be because the transducer had to be very shallow, not to interfere with the propeller, that cannot be stopped.
2003 02 11 12:06 GMT	Started the first CTD (with LADCP) station, no. 29, on Track 2 at 74°40'S, 30°W towards W.

2003 02 12 14:10 GMT	The CTD system stopped functioning, while profiling station 38. Due to slippage between the cable drum and the slip-ring system, the leads had been twisted and torn. After repair, station 38 was reoccupied.
2003 02 13 06:34 GMT	Started the last CTD station, no. 41, on Track 2 at 74°40’S, 36°W.
2003 02 13 08:01 GMT	Started the first CTD station, no. 42, on Track 3 at 74°37’S, 35°56’W towards NNE.
2003 02 13 10:55 GMT	Started station 44 at 74°32’S, 35°47’W. After this station, Track 3 had to be aborted due to bad ice conditions.
2003 02 13	Decided to try a CTD section along 34°W and sailed eastwards. This plan had to be abandoned due to bad ice conditions. Instead, it was decided to occupy CTD stations farther east, close to the northeasternmost section on Figure 3 in the cruise plan, where ice conditions were more favourable.
2003 02 14 16:43 GMT	Started the first CTD station, no. 45, on Track 4 at 74°25’S, 32°W towards N.
2003 02 15 12:30 GMT	Started the last CTD station, no. 56, on Track 4 at 73°46’S, 31° 47’W.
2003 02 15 18:01 GMT	Started the first CTD station, no. 57, on Track 5 at 73°50’S, 30°W towards S.
2003 02 16 13:41 GMT	Started the last CTD station, no. 67, on Track 5 at 74°36’S, 30°W.
2003 02 16 15:04 GMT	Started the first CTD station, no. 68, on Track 6 at 74°34’S, 29° 45’W towards NE.
2003 02 16 16:00 GMT	After profiling station 68, the sea cable had acquired a knot, some 40m above the CTD. This part of the cable was discarded and the cable re-terminated. The CTD still did not function and it appeared that the sea cable bulkhead connector on the CTD was shorted. A new bulkhead connector was cannibalised from the spare CTD. The CTD now seemed to function properly.
2003 02 17 12:30 GMT	While profiling station 75, the CTD stopped functioning. The sea cable bulkhead connector on the CTD was again shorted and had shorted both the connector on the sea cable and on the test cable. The bulkhead connector on the bottom sensor was cannibalised for the CTD and the mating connector on a test cable was cannibalised for the sea cable. To save time, station 75 was not reoccupied.
2003 02 17 22:48 GMT	Started the last CTD station, no. 76, on Track 6 at 74°18’S, 27° 45’W.
2003 02 18 01:58 GMT	Started the first CTD station, no. 77, on Track 7 at 74°18’S, 27° 10’W towards S.
2003 02 18 16:06 GMT	Started the last CTD station, no. 84, on Track 7 at 74°38’S, 26° 55’W.
2003 02 18 19:25 GMT	Started the first CTD station, no. 85, on Track 8 at 74°27’S, 26° 19’W towards SE.
2003 02 19 04:12 GMT	Started the last CTD station, no. 91, on Track 8 and on the cruise at 74°37’S, 25° 32’W. It had been the intention to have shorter station spacing on this section, in order to trace the coastal current properly. Bad weather prevented this.

Appendix B: Complete station list

Comments:

Corrected values for bottom depths are based on echosounder sound velocity settings (1500 m/s up to and including CTD station 19, 1445 m/s after that) and measured CTD profile from station 57.

From station 29, onwards, the ADCP was used with the CTD whenever the bottom depth was less than 1000m.

On each CTD station, double salinity samples were taken at one depth, except for the last part of the cruise, where scarcity of bottles and plastic inserts reduced the salinity sampling to every second station.

On most stations, samples were taken for O18 analysis from 4 different depths.

List of CTD and LADCP stations on RRS Ernest Shackleton cruise to the Weddell Sea Feb. 2003

No	Date	Time	Latitude	Longitude	Depth	Gear	Samples/Comment
1	Feb 09 2003	00:10	76 10.01 S	27 30.27 W	286	CTD	1 sal. + 1 O-18
2	Feb 09 2003	01:20	76 08.05 S	27 38.36 W	356	CTD	1 sal. + 2 O-18
3	Feb 09 2003	03:27	76 05.84 S	27 46.72 W	337	CTD	1 sal. + 3 O-18
4	Feb 09 2003	03:27	76 03.73 S	27 55.53 W	330	CTD	1 sal. + 3 O-18
5	Feb 09 2003	04:21	76 01.77 S	28 03.81 W	375	CTD	1 sal. + 3 O-18
6	Feb 09 2003	05:26	75 59.54 S	28 12.00 W	354	CTD	1 sal. + 3 O-18
7	Feb 09 2003	06:16	75 57.38 S	28 20.38 W	365	CTD	1 sal. + 3 O-18
8	Feb 09 2003	07:07	75 55.31 S	28 28.06 W	363	CTD	1 sal. + 2 O-18
9	Feb 09 2003	08:36	75 52.17 S	28 37.71 W	386	CTD	1 sal. + 2 O-18
10	Feb 09 2003	09:23	75 49.63 S	28 50.78 W	444	CTD	1 sal. + 3 O-18
11	Feb 09 2003	10:31	75 46.14 S	29 04.62 W	406	CTD	1 sal. + 4 O-18
12	Feb 09 2003	11:51	75 42.51 S	29 18.42 W	452	CTD	1 sal. + 4 O-18
13	Feb 09 2003	13:06	75 38.88 S	29 32.48 W	467	CTD	1 sal. + 4 O-18
14	Feb 09 2003	14:06	75 35.39 S	29 46.63 W	432	CTD	1 sal. + 4 O-18
15	Feb 09 2003	15:07	75 31.75 S	30 00.26 W	434	CTD	1 sal. + 3 O-18
16	Feb 09 2003	16:10	75 28.09 S	30 14.30 W	421	CTD	1 sal. + 3 O-18
17	Feb 09 2003	17:13	75 24.44 S	30 28.32 W	438	CTD	1 sal. + 4 O-18
18	Feb 09 2003	18:03	75 22.22 S	30 36.49 W	457	CTD	1 sal. + 4 O-18
19	Feb 09 2003	19:00	75 20.02 S	30 44.78 W	482	CTD	1 sal. + 4 O-18
20	Feb 10 2003	00:01	75 18.01 S	30 53.74 W	548	CTD	1 sal. + 4 O-18
21	Feb 10 2003	01:38	75 15.71 S	31 02.83 W	590	CTD	1 sal. + 4 O-18
22	Feb 10 2003	03:34	75 13.36 S	31 10.61 W	616	CTD	1 sal. + 4 O-18
23	Feb 10 2003	04:46	75 11.15 S	31 18.39 W	628	CTD	1 sal. + 4 O-18
24	Feb 10 2003	06:20	75 08.92 S	31 26.45 W	626	CTD	1 sal. + 4 O-18
25	Feb 10 2003	07:33	75 06.67 S	31 35.09 W	631	CTD	1 sal. + 4 O-18
26	Feb 10 2003	09:00	75 04.42 S	31 43.56 W	621	CTD	1 sal. + 4 O-18
27	Feb 10 2003	10:11	75 02.21 S	31 51.04 W	614	CTD	1 sal. + 4 O-18
28	Feb 10 2003	11:36	75 00.12 S	32 00.59 W	607	CTD	1 sal. + 4 O-18
29	Feb 11 2003	12:06	74 40.06 S	29 59.94 W	422	CTD+LADCP	1 sal. + 4 O-18
30	Feb 11 2003	13:28	74 40.07 S	30 30.22 W	455	CTD+LADCP	1 sal. + 4 O-18
31	Feb 11 2003	14:52	74 40.01 S	31 00.16 W	515	CTD+LADCP	1 sal. + 4 O-18
32	Feb 11 2003	16:40	74 42.36 S	31 30.32 W	579	CTD+LADCP	1 sal. + 4 O-18
33	Feb 11 2003	22:04	74 38.61 S	31 56.20 W	601	CTD+LADCP	1 sal. + 4 O-18
34	Feb 12 2003	02:10	74 38.56 S	32 28.45 W	596	CTD+LADCP	1 sal. + 4 O-18
35	Feb 12 2003	05:29	74 40.16 S	33 00.91 W	588	CTD+LADCP	1 sal. + 4 O-18
36	Feb 12 2003	08:11	74 39.42 S	33 30.49 W	579	CTD+LADCP	1 sal. + 4 O-18
37	Feb 12 2003	10:47	74 39.86 S	34 00.12 W	548	CTD+LADCP	1 sal. + 4 O-18
38	Feb 12 2003	18:10	74 40.16 S	34 28.45 W	527	CTD+LADCP	1 sal. + 3 O-18
39	Feb 12 2003	22:19	74 39.87 S	35 00.07 W	497	CTD+LADCP	1 sal. + 4 O-18
40	Feb 13 2003	02:41	74 39.81 S	35 27.81 W	458	CTD+LADCP	1 sal. + 4 O-18
41	Feb 13 2003	06:34	74 40.07 S	35 59.82 W	415	CTD+LADCP	1 sal. + 4 O-18
42	Feb 13 2003	08:01	74 37.26 S	35 55.79 W	420	CTD+LADCP	1 sal. + 4 O-18

43	Feb 13 2003	09:37	74 34.41 S	35 51.60 W	437	CTD+LADCP	1 sal. + 4 O-18
44	Feb 13 2003	10:57	74 31.81 S	35 47.54 W	561	CTD+LADCP	1 sal. + 4 O-18
45	Feb 14 2003	16:43	74 24.96 S	32 00.07 W	585	CTD+LADCP	1 sal. + 2 O-18
46	Feb 14 2003	17:40	74 21.96 S	32 00.13 W	590	CTD+LADCP	1 sal. + 4 O-18
47	Feb 14 2003	18:54	74 19.02 S	32 00.23 W	752	CTD+LADCP	1 sal. + 4 O-18
48	Feb 14 2003	20:06	74 15.98 S	32 00.05 W	952	CTD+LADCP	1 sal. + 3 O-18
49	Feb 14 2003	21:36	74 12.98 S	32 00.37 W	1134	CTD	1 sal. + 4 O-18
50	Feb 14 2003	23:03	74 10.04 S	31 59.98 W	1302	CTD	1 sal. + 4 O-18
51	Feb 15 2003	00:39	74 06.97 S	31 59.98 W	1468	CTD	1 sal. + 4 O-18
52	Feb 15 2003	02:10	74 03.95 S	32 00.14 W	1630	CTD	1 sal. + 4 O-18
53	Feb 15 2003	04:17	74 00.92 S	31 59.89 W	1773	CTD	1 sal. + 3 O-18
54	Feb 15 2003	07:09	73 56.08 S	31 59.55 W	1981	CTD	1 sal. + 4 O-18
55	Feb 15 2003	09:54	73 51.12 S	31 44.03 W	2213	CTD	1 sal. + 3 O-18
56	Feb 15 2003	12:30	73 45.94 S	31 46.54 W	2399	CTD	1 sal. + 4 O-18
57	Feb 15 2003	18:01	73 50.04 S	30 00.15 W	2548	CTD	4 O-18
58	Feb 15 2003	20:49	73 55.02 S	29 59.92 W	2457	CTD	1 sal. + 4 O-18
59	Feb 15 2003	22:56	73 59.97 S	30 00.03 W	2218	CTD	4 O-18
60	Feb 16 2003	01:41	74 04.91 S	29 59.98 W	2048	CTD	1 sal. + 4 O-18
61	Feb 16 2003	03:47	74 10.01 S	29 59.95 W	1869	CTD	4 O-18
62	Feb 16 2003	05:58	74 15.03 S	29 59.78 W	1674	CTD	1 sal. + 4 O-18
63	Feb 16 2003	07:48	74 19.99 S	30 00.15 W	1415	CTD	4 O-18
64	Feb 16 2003	09:36	74 24.98 S	30 00.22 W	1138	CTD	1 sal. + 4 O-18
65	Feb 16 2003	11:16	74 29.95 S	29 59.76 W	874	CTD+LADCP	4 O-18
66	Feb 16 2003	12:31	74 32.95 S	29 59.97 W	646	CTD+LADCP	1 sal. + 4 O-18
67	Feb 16 2003	13:41	74 35.95 S	30 00.73 W	429	CTD+LADCP	4 O-18
68	Feb 16 2003	15:04	74 34.00 S	29 45.08 W	795	CTD+LADCP	4 O-18
69	Feb 17 2003	00:22	74 31.86 S	29 29.30 W	1070	CTD	1 sal. + 4 O-18
70	Feb 17 2003	02:05	74 29.96 S	29 15.30 W	1273	CTD	4 O-18
71	Feb 17 2003	03:54	74 27.98 S	29 00.08 W	1509	CTD	1 sal. + 4 O-18
72	Feb 17 2003	06:04	74 25.99 S	28 44.99 W	1700	CTD	4 O-18
73	Feb 17 2003	08:00	74 24.07 S	28 29.94 W	1872	CTD	1 sal. + 4 O-18
74	Feb 17 2003	10:06	74 22.00 S	28 15.08 W	2025	CTD	4 O-18
75	Feb 17 2003	19:22	74 19.93 S	27 59.89 W	2179	CTD	Prof. not compl.
76	Feb 17 2003	22:48	74 18.00 S	27 45.01 W	2319	CTD	1 sal. + 4 O-18
77	Feb 18 2003	01:58	74 18.01 S	27 09.99 W	2498	CTD	4 O-18
78	Feb 18 2003	05:16	74 25.01 S	27 10.04 W	2311	CTD	1 sal. + 4 O-18
79	Feb 18 2003	08:09	74 31.92 S	27 09.76 W	2044	CTD	4 O-18
80	Feb 18 2003	10:21	74 33.92 S	27 04.98 W	1761	CTD	1 sal. + 4 O-18
81	Feb 18 2003	11:54	74 35.06 S	27 02.11 W	1397	CTD	4 O-18
82	Feb 18 2003	13:25	74 36.02 S	27 00.46 W	1040	CTD	1 sal. + 4 O-18
83	Feb 18 2003	15:01	74 37.55 S	26 57.10 W	616	CTD+LADCP	4 O-18
84	Feb 18 2003	16:06	74 38.01 S	26 54.92 W	466	CTD+LADCP	1 sal. + 4 O-18
85	Feb 18 2003	19:25	74 27.24 S	26 19.11 W	1020	CTD+LADCP	4 O-18
86	Feb 18 2003	20:26	74 27.91 S	26 15.77 W	776	CTD+LADCP	1 sal. + 4 O-18
87	Feb 18 2003	21:18	74 28.50 S	26 12.71 W	589	CTD+LADCP	4 O-18
88	Feb 18 2003	22:48	74 32.04 S	25 54.86 W	527	CTD+LADCP	1 sal. + 4 O-18
89	Feb 19 2003	01:31	74 34.28 S	25 43.40 W	545	CTD+LADCP	4 O-18
90	Feb 19 2003	02:48	74 35.59 S	25 37.43 W	451	CTD+LADCP	1 sal. + 4 O-18
91	Feb 19 2003	04:12	74 36.95 S	25 31.47 W	565	CTD+LADCP	1 sal. + 4 O-18

Comments:

Time and position are for start of the CTD cast. Bottom depth is the (corrected) depth, when the CTD was close to bottom and, in some cases, may differ from depth at station start.

Values for bottom depths are corrected, based on echosounder sound velocity settings (1500 m/s up to and including CTD station 19, 1445 m/s after that) and measured CTD profile from station 57. Note that the depths in the header files are uncorrected echosounder values for station start.

Each salinity sample (sal.) includes two sample bottles from the same Niskin bottle. The O-18 samples were stored in one bottle from each depth.

Appendix C: Instruments and methods

The primary instrument used during the cruise was the CTD, a Seabird Electronics (SBE) 911plus system, with the SBE 9plus underwater unit fitted with single temperature and conductivity sensors. Serial numbers and calibration dates are given in the table below:

Sensor/Instrument	Serial no.	Calibration date
CTD Underwater unit	09P 15041-0471	(19 Feb 1997)
Temperature	03 2313	10 May 2000
Conductivity	04 1878	11 May 2000
Pressure (Digiquartz)	69002	5 Dec 1996 with recalibration 18 Feb 1997

In addition, the CTD was connected to a SBE32 12-bottle sub-compact carousel water sampler, with four 1.7-liter Niskin bottles. The SBE11plus deck unit was connected to a Garmin GPS45XL GPS through the NMEA input. In all but the first three profiles, the starting time and position was recorded into the header from the GPS. Starting with station 32, all LADCP stations have continuously recorded GPS tracks in the raw data (.DAT) files. Note that the GPS positions are appended to every CTD scan (24 times/second) in the raw data file; however, when using a serial connection to the deck unit, they are only updated once a second. Dip switch settings for the temp./cond. delay in the deck unit are the factory defaults, corresponding to a conductivity advance of 1.75 scans (0.073 seconds). CTD data processing follows the standard procedure for SBE911plus data as described in the SeaSoft manual, using the downcast only, with a final bin average into 1 dbar pressure bins. The resulting .CNV and .ASC files contain the following columns:

Scan number	
Temperature	ITS-90 (°C)
Conductivity	S/m
Pressure	dbar
Salinity	PSS78 (psu)
Density σ_θ (γ?)	Sigma-theta (kg/m^3)
Density σ_2	Sigma-2 (kg/m^3)
Flag	(should be 0 in all included bins)

In addition, a separate file to assist LADCP processing was extracted, bin averaged into 1-second time bins, and given the extension .POS; it is in the same format as .CNV files, with the following columns:

Time	seconds after profile start (profile start time is included in header)
Latitude	decimal degrees
Longitude	decimal degrees
Pressure	dbar

The headers in both files contain echo depth and station numbers. In addition, fired bottle data was extracted into .BTL files, which contain bottle salinity, temperature, and pressure information.

The LADCP was an RD Instruments 300 kHz Workhorse Sentinel ADCP, in a 1000 dbar pressure casing, with 30 MB flash rom installed in one PCMCIA card slot. The instrument was started before deployment, and the resulting data files were then retrieved after recovery, and the data storage erased. For unknown reasons, some stations' main data files were named "stXXX001.000", and some were named "stXXX000.000", where XXX is the station number. However, if there were two files, the first would be around 30 kB, while the second usually was >2 MB, making it easy to differentiate between them.
LADCP data processing was done using the Matlab LADCP software package v. 6, written by Martin Visbeck at Lamont Doherty Earth Observatory (LDEO) of Columbia University. The routines "loadnav" and "loadctd" were customized to read the information stored in the ".POS" files described above. In addition, the computerized log file, "LADCPLOG.TXT" was read in to find the last entry for each station number. The log contains the maximum depth and the start and end positions and times. The magnetic deviation in the study area was around 2° E, but for this preliminary data processing, deviation was set to 0. After all this information was loaded into the parameter structure p using the default processing script, the processing was run, resulting in ".mat" files being produced in each station directory. These files contain the various resulting data, mostly stored in the structure "dr"; for more information, see the LADCP package documentation.
Successful processing was run for all stations except 66 and 68; the first LADCP stations up to no. 32 were processed without utilizing the CTD data, as the position was not recorded continuously.